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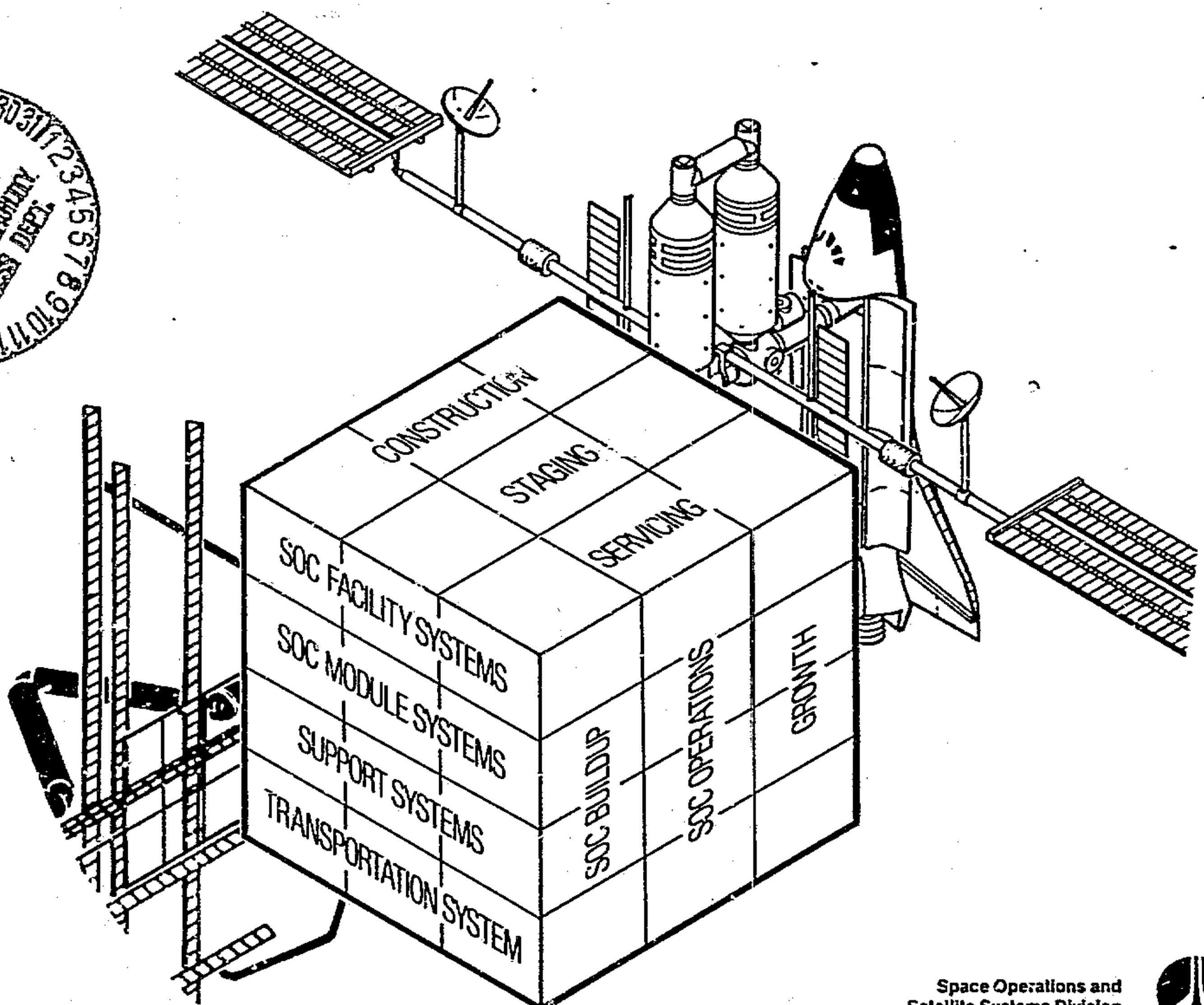
NAS9-16153
PD80-55

SPACE OPERATIONS CENTER—SHUTTLE INTERACTION STUDY

FIRST QUARTERLY REVIEW



Space Operations and Satellite Systems Division

Rockwell International

FOREWARD

This briefing package contains the material presented at the first quarterly review of the SOC - Shuttle Interaction Study. This study is being performed under NASA contract NAS9-16153 and is conducted under the technical direction of the Contracting Officer's Representative (COR), Samuel H. Nassif, Systems Design, Johnson Space Center.

These materials cover the first three study tasks. Written discussions accompany a number of the charts where deemed appropriate because of complex subject matter.

BRIEFING OUTLINE

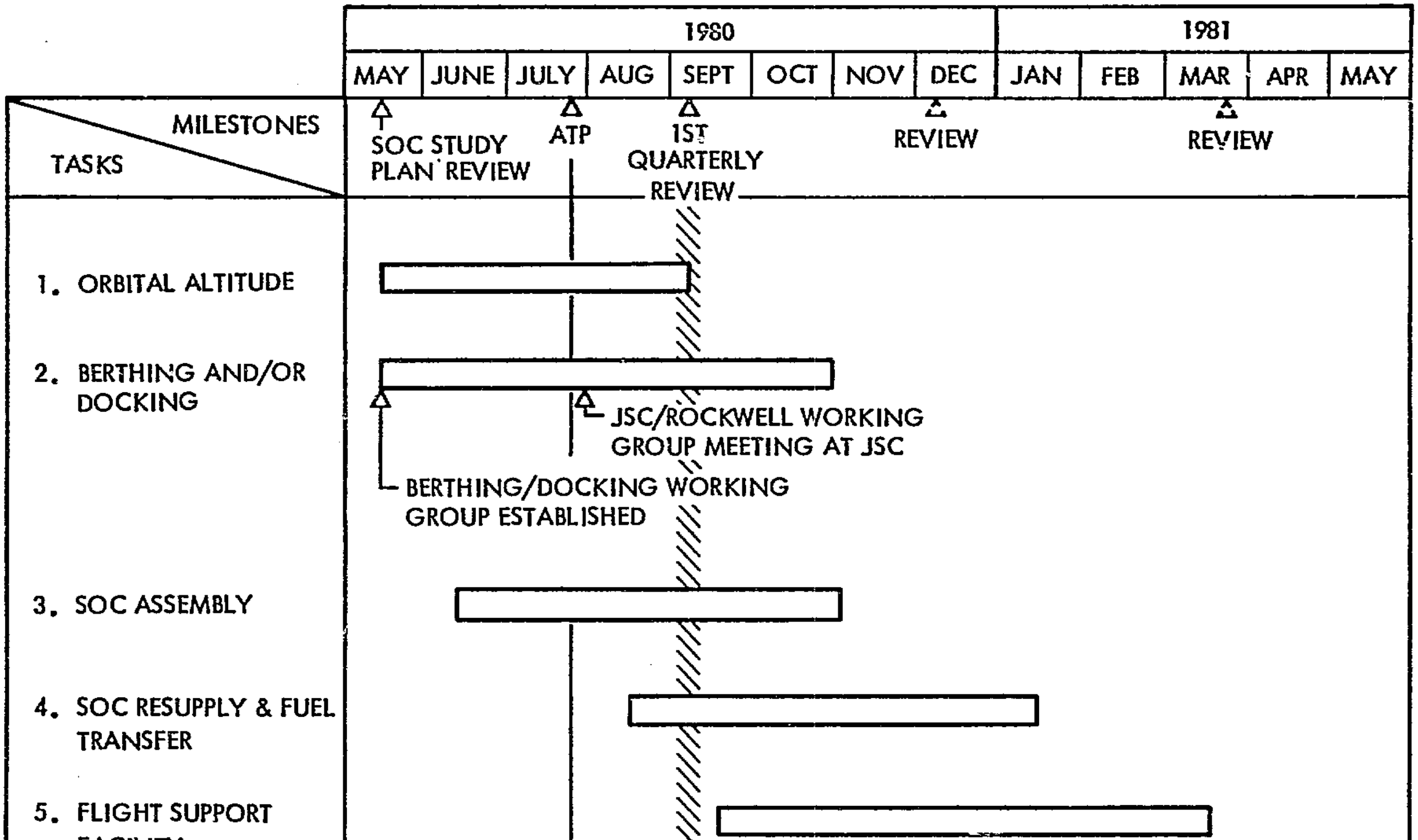
- EXECUTIVE SUMMARY
- ORBIT ALTITUDE STRATEGY
- BERTHING & DOCKING
- SOC BUILDUP & ASSEMBLY CONCEPTS
- CONCLUSIONS & PLANS

STUDY OBJECTIVE*

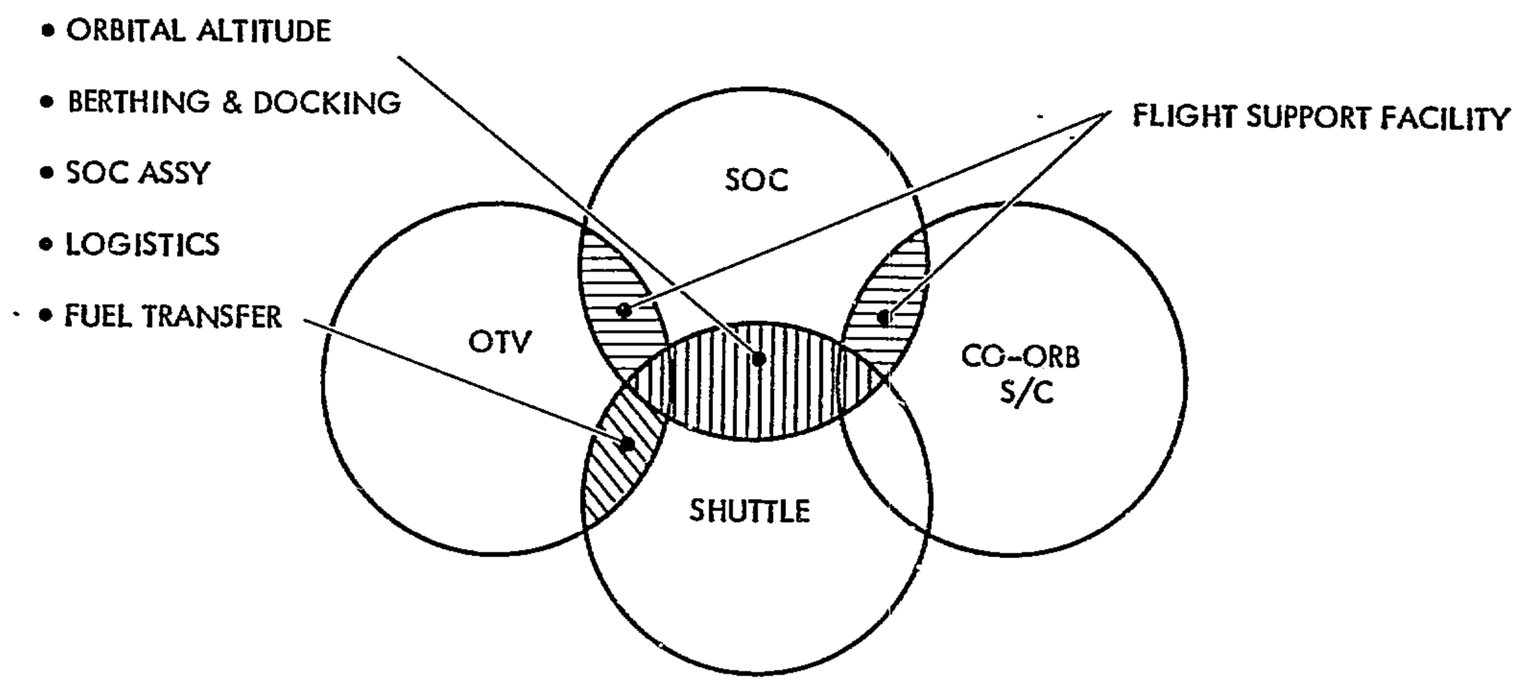
"ANALYZE, IN A PRELIMINARY FASHION, THE IMPLICATION OF USING THE SHUTTLE WITH THE SOC, INCLUDING CONSTRAINTS THAT THE SHUTTLE WILL PLACE UPON THE SOC DESIGN. IDENTIFY ALL THE CONSIDERATIONS INVOLVED IN THE USE OF THE SHUTTLE AS A PART OF THE SOC CONCEPT."

*SOW, NAS9-16153 CONTRACT

STUDY ACTIVITY SCHEDULE



STUDY ISSUES

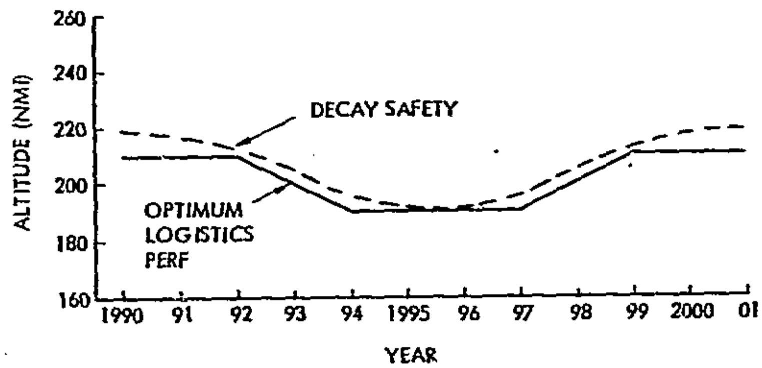


IMPACT CRITERIA:

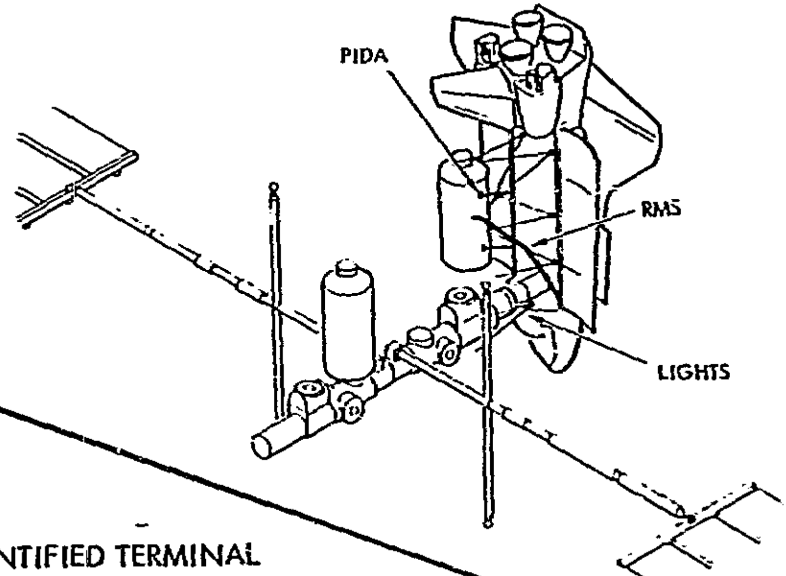
- SOC CONFIGURATION
- PERFORMANCE/OPS CAPABILITY OF SOC
- MODS TO SHUTTLE
- SHUTTLE FLEET UTILIZATION
- TECHNOLOGY REQUIREMENTS
- MOTV REQUIREMENTS

ACCOMPLISHMENTS

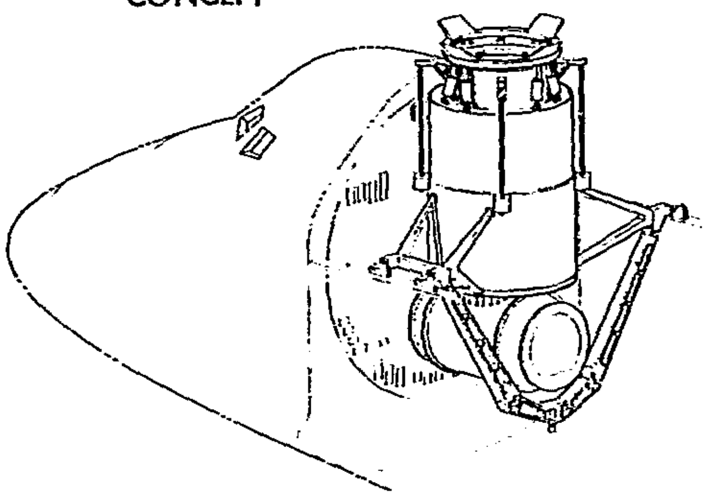
• ESTABLISHED AN ORBIT ALTITUDE STRATEGY



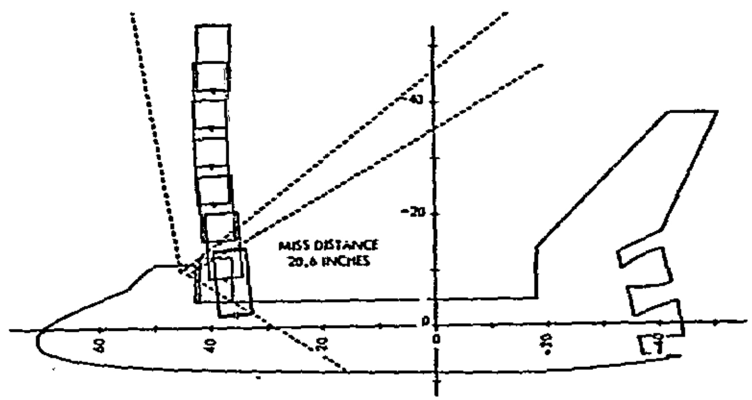
• IDENTIFIED SOC ASSEMBLY IMPLICATIONS



• ESTABLISHED A DOCKING MODULE CONCEPT



• IDENTIFIED TERMINAL CLOSURE IMPLICATIONS

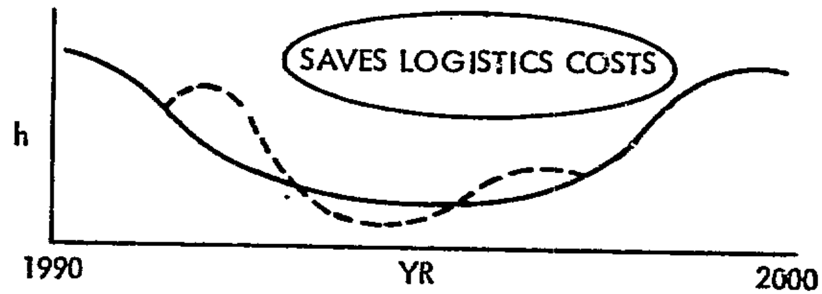


SOC ORBIT ALTITUDE

USE VARIABLE ALTITUDE STRATEGY

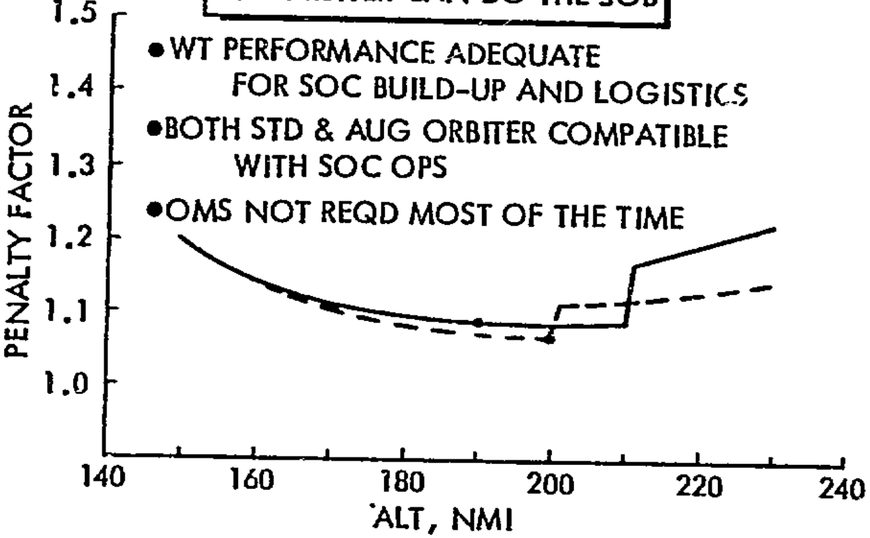
FLY HIGH ALT
- LO TRAFFIC
- HI ATMOS DENSITY

FLY LOW ALT
- HI TRAFFIC
- LOW ATMOS DENSITY



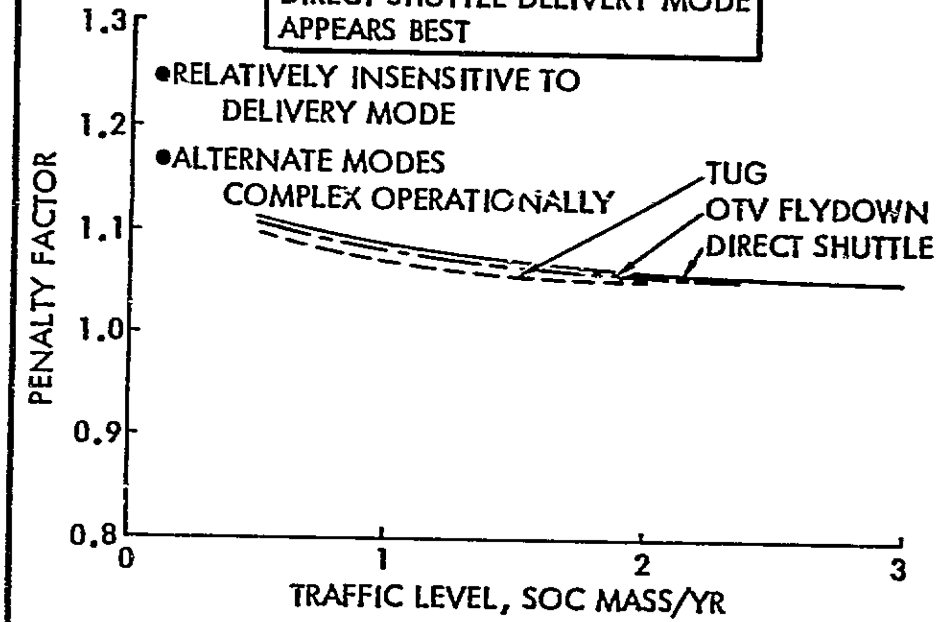
STD ORBITER CAN DO THE JOB

- WT PERFORMANCE ADEQUATE FOR SOC BUILD-UP AND LOGISTICS
- BOTH STD & AUG ORBITER COMPATIBLE WITH SOC OPS
- OMS NOT REQD MOST OF THE TIME



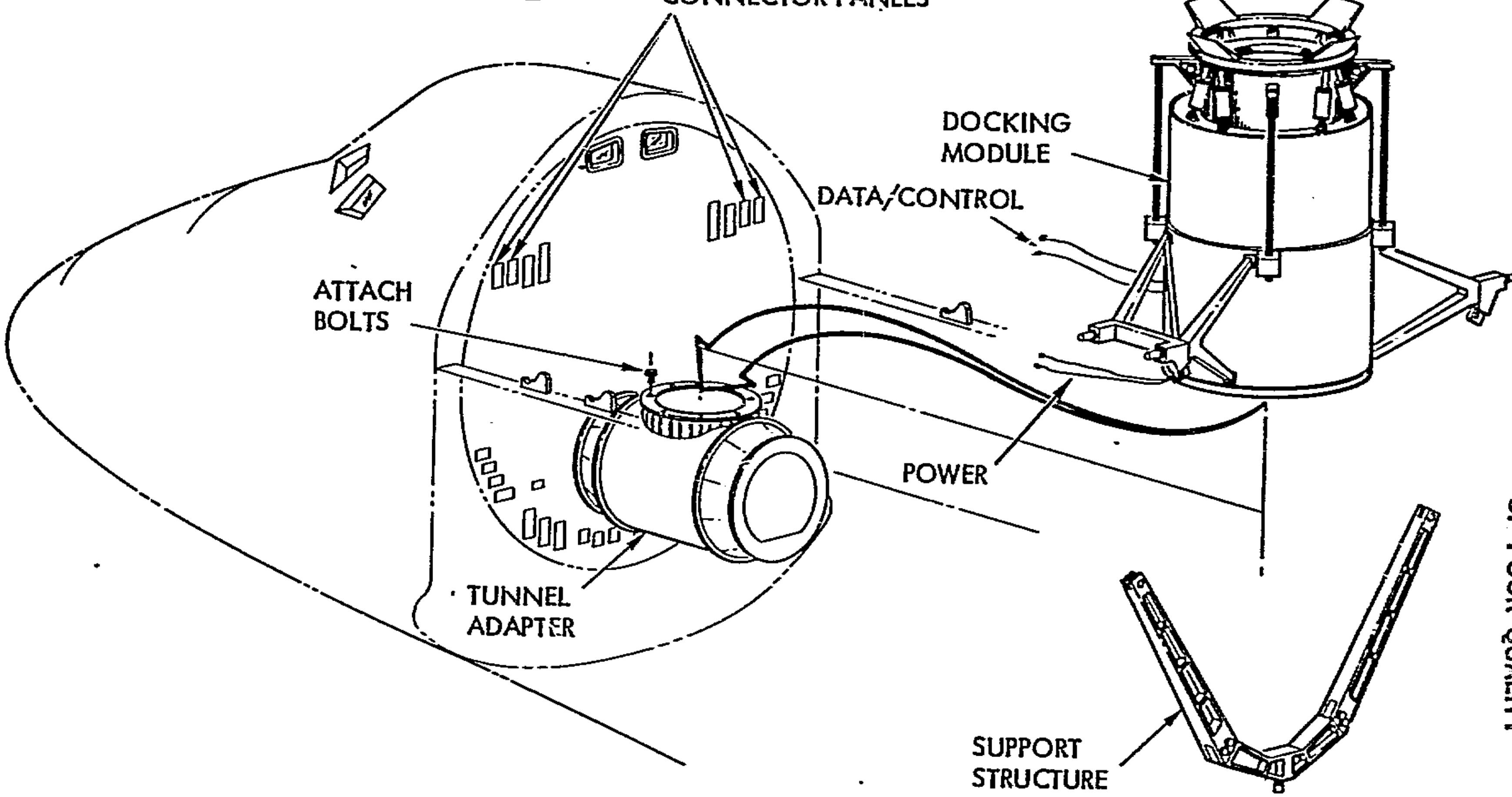
DIRECT SHUTTLE DELIVERY MODE APPEARS BEST

- RELATIVELY INSENSITIVE TO DELIVERY MODE
- ALTERNATE MODES COMPLEX OPERATIONALLY

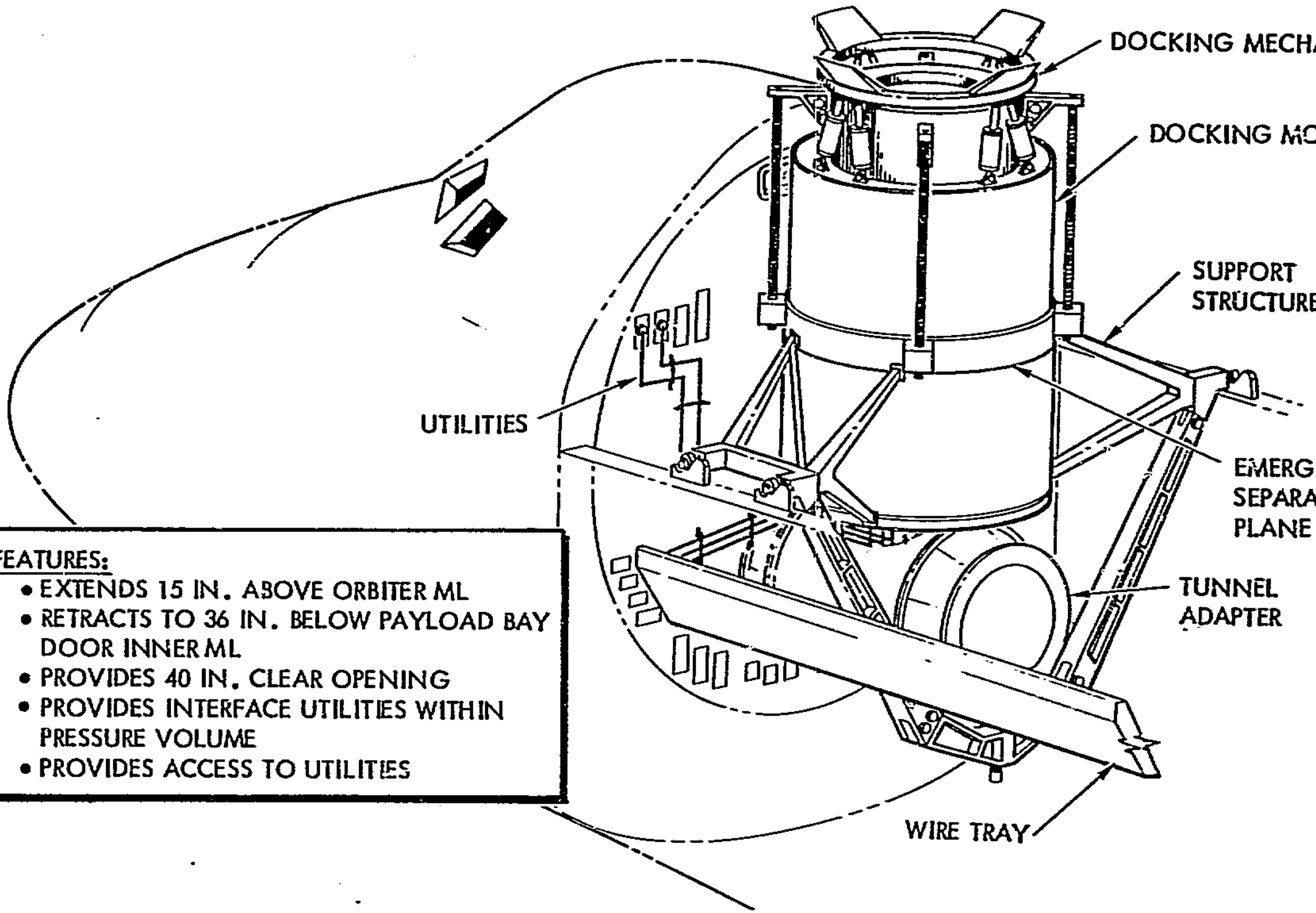


DOCKING MODULE CONCEPT

DOCKING MODULE IS DESIGNED FOR EASY CHANGEOUT - LIKE CARGO



DOCKING MODULE FEATURES



FEATURES:

- EXTENDS 15 IN. ABOVE ORBITER ML
- RETRACTS TO 36 IN. BELOW PAYLOAD BAY DOOR INNER ML
- PROVIDES 40 IN. CLEAR OPENING
- PROVIDES INTERFACE UTILITIES WITHIN PRESSURE VOLUME
- PROVIDES ACCESS TO UTILITIES

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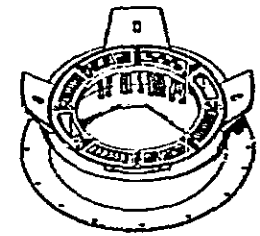
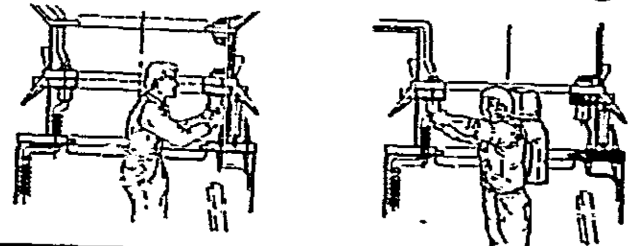
DOCKING MODULE CHARACTERISTICS

- **UTILITIES INTERFACES:**
  - ADEQUATE AVAILABLE AREA ....

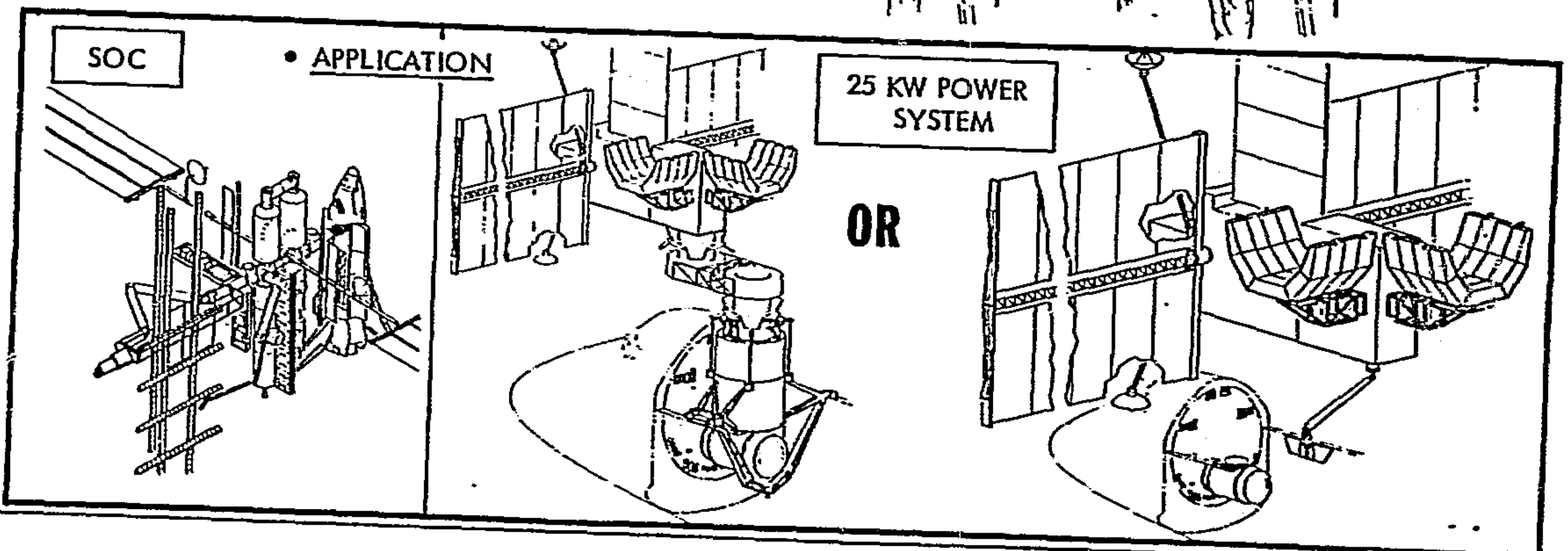


  - REMOTE CONNECTIONS ....

  - SERVICEABLE ....



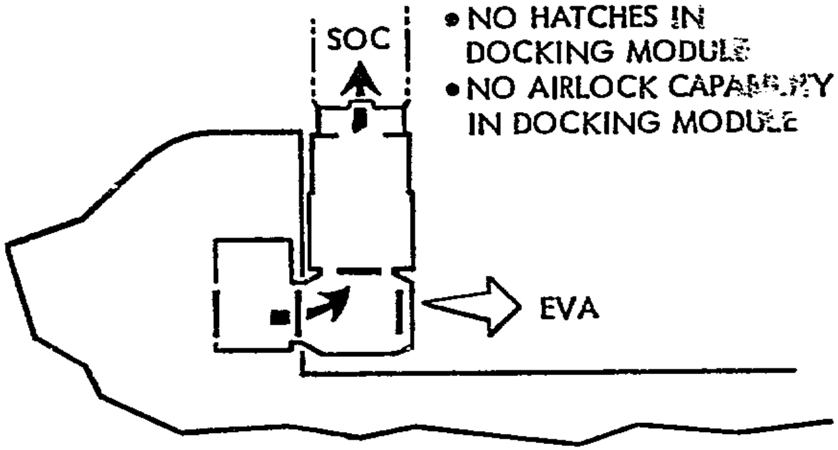
- APPLICATION



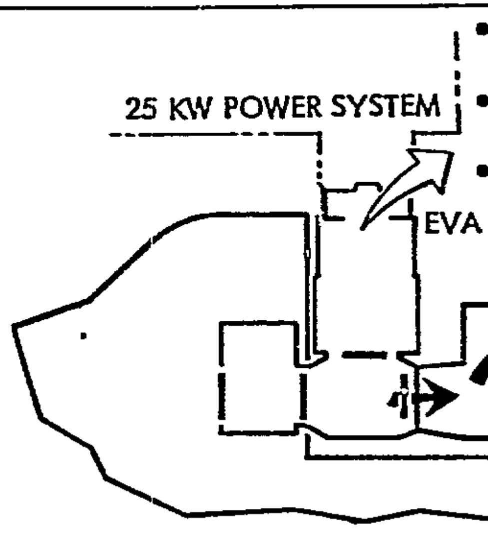
EVA OPTIONS

This chart illustrates that the proposed docking module concept, if provided with an airlock capability, can provide EVA passage with any combination of payloads.

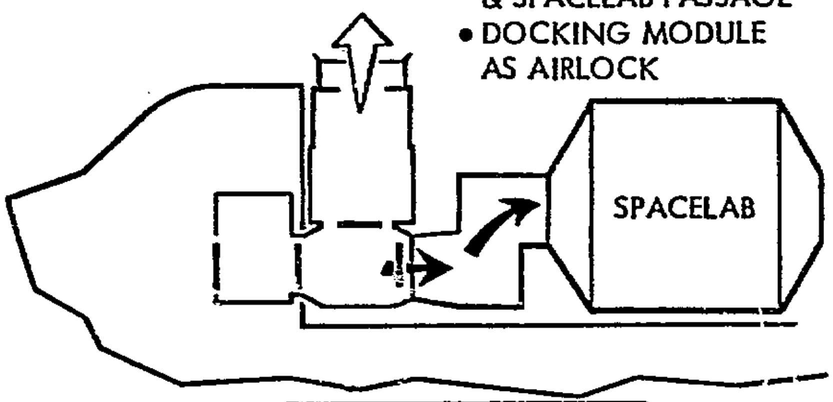
EVA OPTIONS



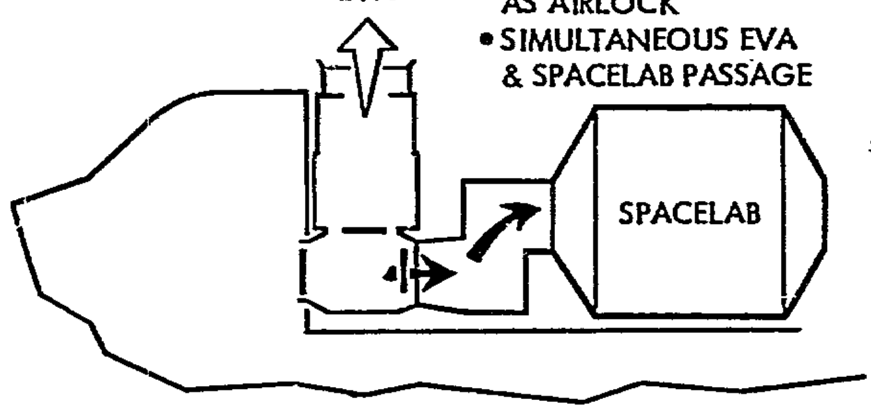
SOC OPERATIONS



POWER SYSTEM OPERATIONS



SPACELAB OPERATIONS



SPACELAB OPERATIONS

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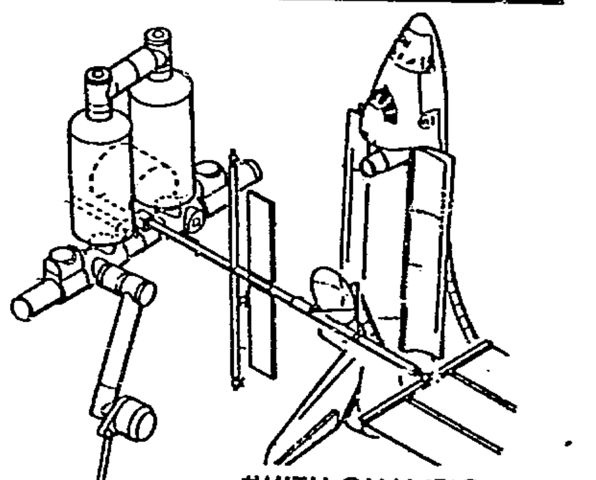
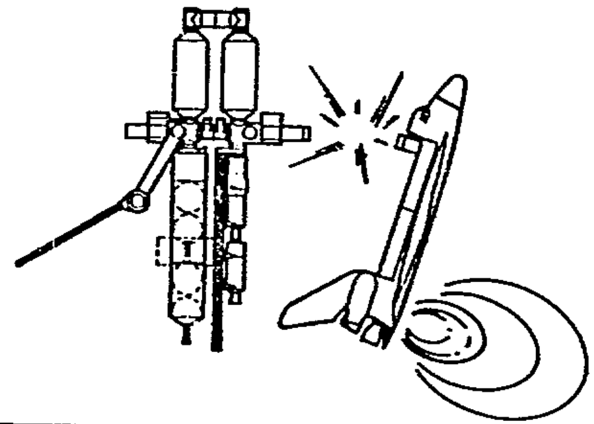
DOCKING OPERATIONS

ORBITER CAN DOCK WITH SOC*

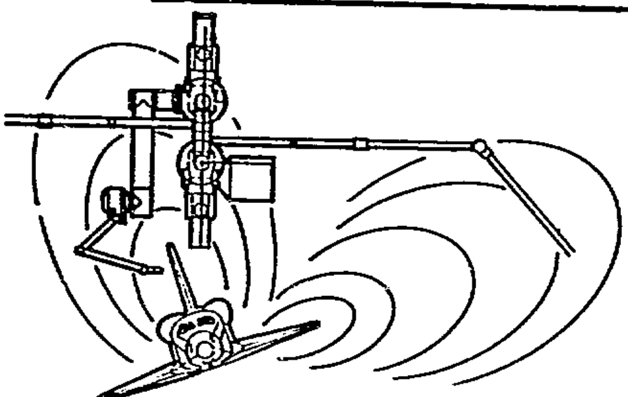


*WITH QUALIFICATIONS

RUNAWAY JET POSES POTENTIAL SAFETY ISSUES



PLUME FROM RCS ABORT THRUSTING COULD AFFECT SOC DESIGN



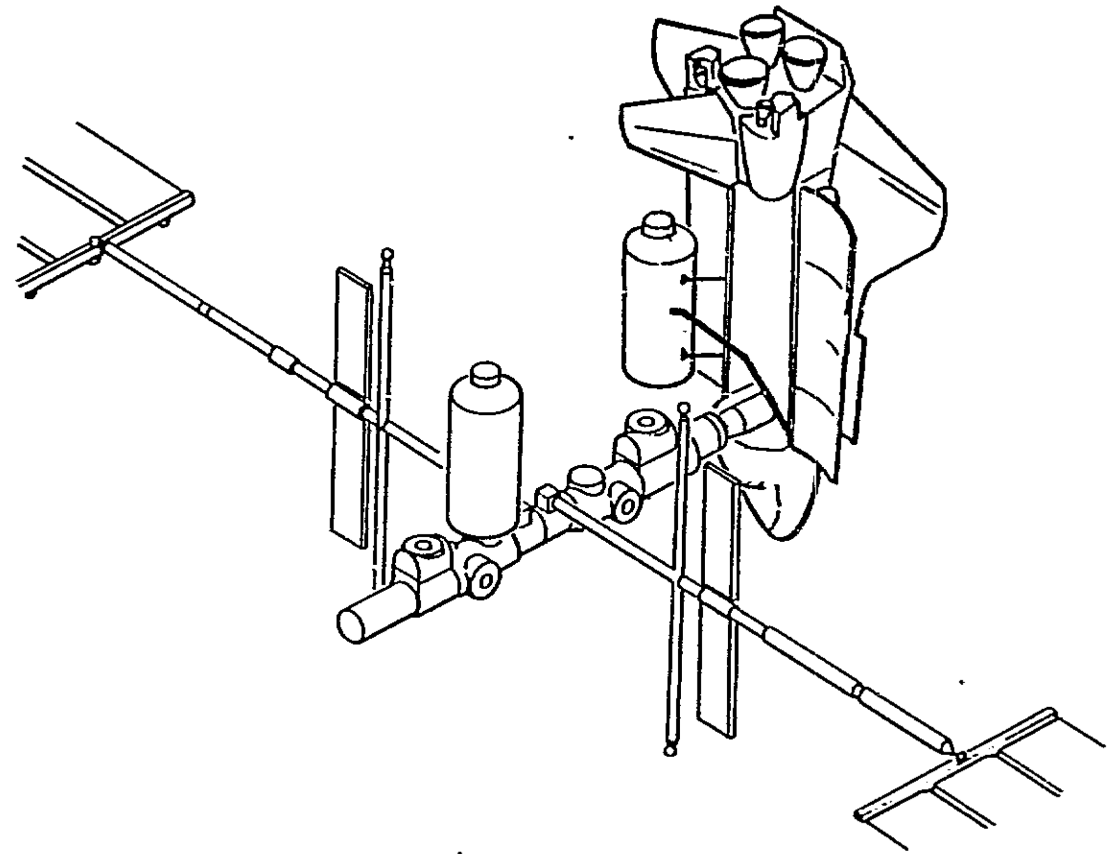
$\Sigma M = 22{,}500$ FT/LB

✓ FURTHER ANALYSES PLANNED
- -EXCURSION ENVELOPES WITH RUNAWAY JETS
- -RMS BERTHING CAPABILITY
- -PLUME IMPINGEMENT EFFECTS

- RECOMMENDED SOC REQMTS KEEP BOTH BERTHING & DOCKING CAPABILITY FOR NOW
- ULTIMATE EVALUATION REQUIRES MAN-IN-THE-LOOP SIMULATIONS

SOC ASSEMBLY

SOC SHOULD BE – AND CAN BE – DESIGNED TO ACCOMMODATE BUILD-UP BY ANY OF SEVERAL SCENARIOS



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POTENTIAL SOC SCENARIOS

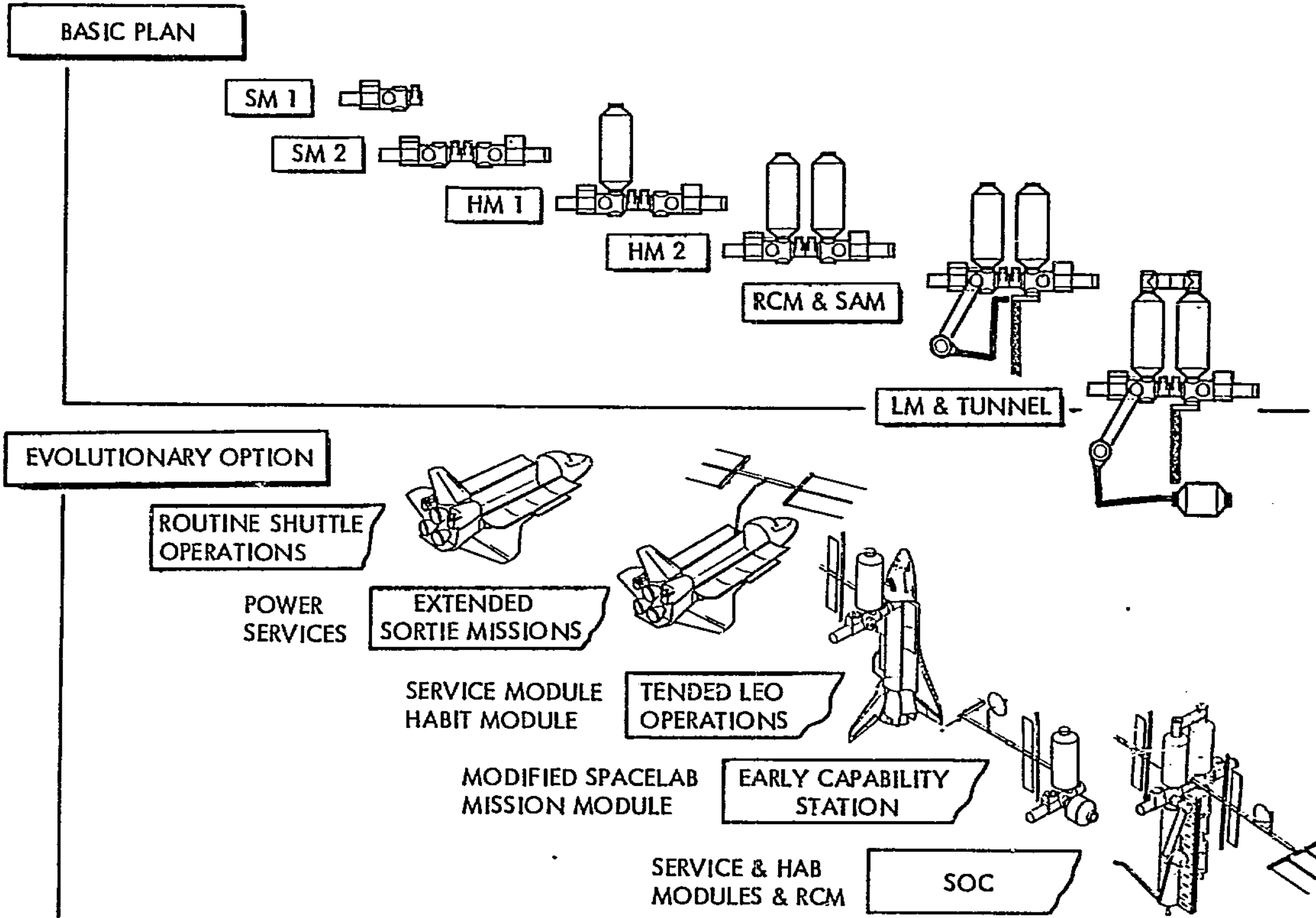
This chart illustrates two possible SOC buildup scenarios. The top scenario depicts the basic plan in which the various SOC modules are produced and delivered in the most logical sequence to achieve "full-up" operational capability in the earliest feasible time period.

This plan, which is in accord with NASA guidelines, has been examined in detail to determine the orbiter's capability to deliver and assemble the SOC system.

The second scenario shows one of many possible "evolutionary" build-up options. In this scenario, the orbiter's sortie capability would first be augmented by the power extension package (PEP). For longer more-advanced missions, the initial SOC service and habitability modules would be assembled to provide necessary services and comfortable crew quarters. Eventually, the economic drive to improve the utilization of the Shuttle fleet might lead to the earliest autonomous SOC. In the case shown, the spacelab might be accommodated as a mission module on the early SOC. However, for accommodation aboard SOC, the spacelab mission module would require extensive modifications in the areas of meteoroid protection, heat rejection, hatches, and structure. Other possible mission modules might include payload pallets.

With the delivery of the remaining modules, the SOC's full-up operational capability would be achieved.

POTENTIAL SOC SCENARIOS



SPACE STATION EVALUATION

This chart presents the main pro's and con's of several space program alternatives leading to permanent manned capability/space station. The basic word content of the chart was taken from Mr. John F. Yardley's presentation to the NASA Council on 4-5 June 1980.

The black arrows at the upper right of the table indicate favorable features associated with the Science and Application Manned Space Platform (SAMSP) concept which could also be captured by the SOC concept with suitable evolutionary buildup approaches. The SOC service module along with a habitability module could be operated initially in a shuttle tended mode with support services designed to the needs and merits of potential users. Thus, SOC could gain these additional favorable program attributes while retaining those already granted to it.

In addition to gaining the above programmatic benefits, evolutionary SOC approaches can negate some of the con's listed on the chart. These are signified by the shaded X's at bottom center of the chart. The SOC service module can be used to support a variety of science and technology missions before habitability capability is added. Also, by following an evolutionary program geared to match the support needs of various users the development funding can be stretched out to avoid high funding peaks. Indeed the developments could actually be paced by the merits of the user programs.

Thus, an evolutionary approach to the SOC program can offer a number of programmatic advantages and should be considered in the design definition of the SOC configuration.

SPACE STATION EVALUATION*

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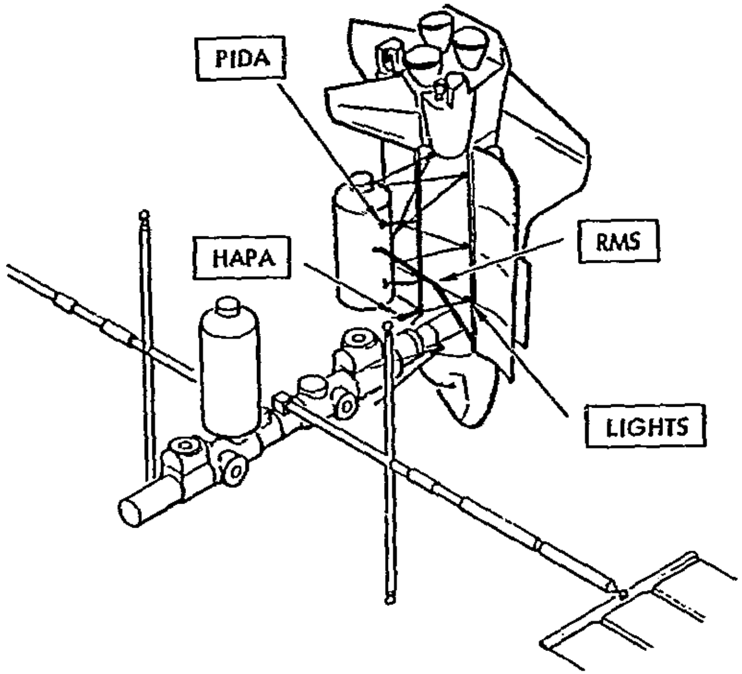
	MOSC	SOC	SAMSP
PRO	• EARLIEST MANNED LONG-DURATION CAPABILITY • USER NEED ORIENTED • LOWEST COST	• PROVIDES LONG-RANGE FOCUS BEYOND 1990 • NECESSARY MAJOR STEP TO GEO SPACE STATION & LARGER CONSTRUCTION OPERATIONS • CAN APPROACH LEVEL OF PREDICTED USSR ACTIVITIES IN LATE 80'S • PROVIDES CONSIDERABLE SAFETY MARGINS FOR PERMANENT OCCUPANCY	• MODULAR & EVOLUTIONARY WITH ALL STEPS SUPPORTABLE BY USERS ON THEIR OWN MERITS • UTILIZES 25 kW POWER SYSTEM FOR POWER, STABILIZATION, CDMS • OPERATED INITIALLY IN SHUTTLE-TENDED MODE (LOW EARLY COSTS) TO BENEFIT SCIENCE MODULES
CON	• NOT CONFIGURED INITIALLY FOR OPERATIONS SUPPORT • LIMITED GROWTH CAPABILITY	• LIMITED SCIENCE CAPABILITY IN INITIAL CONFIGURATION • OTV SUPPORT & LARGE SPACE CONSTRUCTION NOT A "NEEDS" DRIVER TODAY • CONCURRENT DEVELOPMENT OF BASE STATION & OPERATIONAL FACILITIES REQUIRES $1 B PEAK FUNDING	• DELAYS MANNED LONG-DURATION CAPABILITY • COULD LEAD TO AN UNDULY COMPROMISED MANNED SYSTEM • PLACES INCREASED MAN-RATING REQUIREMENTS ON BASIC SASP/25 kW PS

*FROM J.F. YARDLEY PRESENTATION TO NASA COUNCIL 4-5 JUNE, 1980

PROVISIONS FOR SOC ASSEMBLY

ORBITER

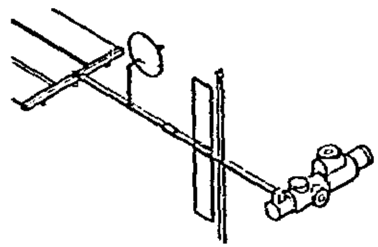
ORBITER PROVISIONS IN DEVELOPMENT OR PLANNED



SOC

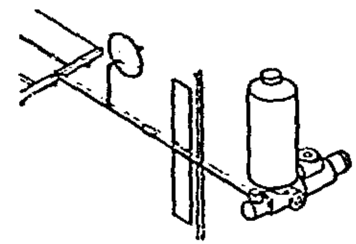
FEW Δ PROVISIONS REQUIRED OF SOC TO ACCOMMODATE ALL POSSIBLE BUILD-UP MODES

SM



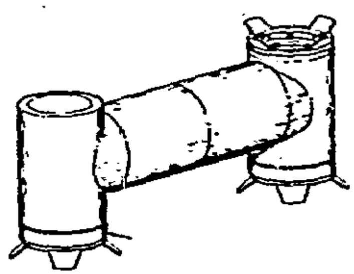
- INTERIM ATTITUDE STABILIZATION FOR SAFE REVISIT

HAB. MODULE



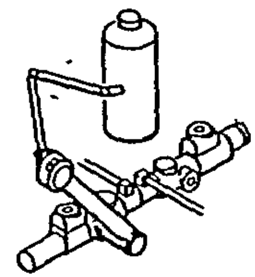
- SHOULD HAVE INDEPENDENT ECLSS FOR MAX FLEXIBILITY

TUNNEL



- PROVIDE FOR POTENTIAL CLOCKING

RCM



- NO IMPACT

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CONCLUSIONS

- SOC SHOULD FLY A VARIABLE ALTITUDE STRATEGY -- COMBINES SAFETY WITH EFFICIENCY
- STANDARD ORBITER CAN DO THE JOB
- STATUS OF ORBITER MCR AND 25 KW POWER SYSTEM PROGRAMS DEMANDS EARLY DEFINITION OF REQUIREMENTS AND STANDARDIZATION
- ORBITER HAS ADEQUATE CONTROLLABILITY TO SAFELY DOCK WITH SOC, IF RCS/CONTROL FAILURES CAN BE AVOIDED -- COULD BE CRITICAL TO SOC SAFETY
- THE RCS/CONTROL ISSUE REQUIRES ADVANCED SIMULATIONS FOR RESOLUTION
- SOC CAN BE AND SHOULD BE DESIGNED TO ACCOMMODATE NOMINAL AND EVOLUTIONARY MODES OF BUILD-UP AND VARIATIONS ON THESE MODES
- THE STANDARD ORBITER CAN ASSEMBLE THE SOC WITH AIDS CURRENTLY IN DEVELOPMENT AND PLANNED

BRIEFING OUTLINE

EXECUTIVE SUMMARY

ORBIT ALTITUDE STRATEGY

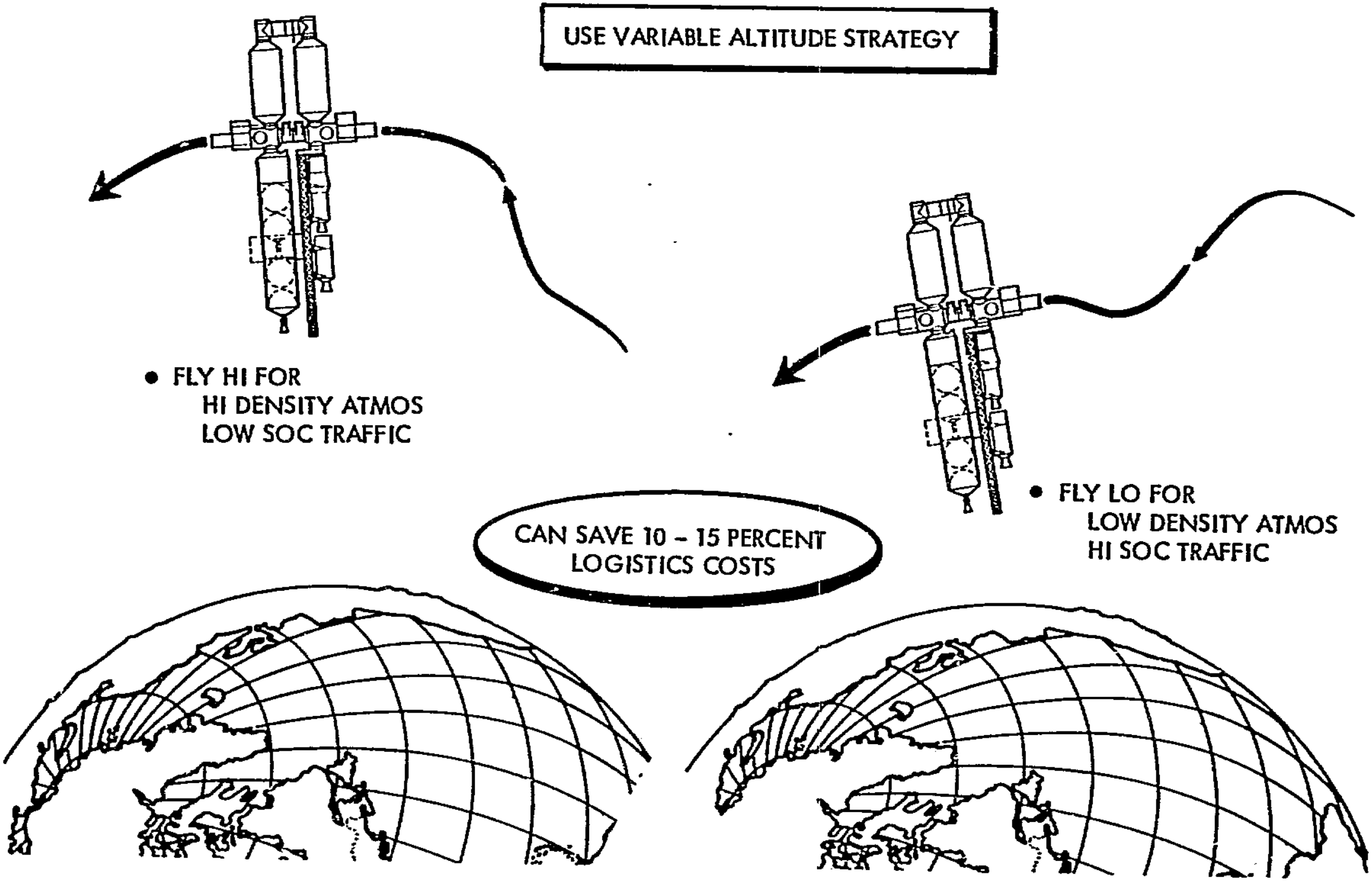
BERTHING & DOCKING

SOC BUILDUP & ASSEMBLY CONCEPTS

CONCLUSIONS & PLANS

SOC ORBIT ALTITUDE

USE VARIABLE ALTITUDE STRATEGY



- FLY HI FOR
  HI DENSITY ATMOS
  LOW SOC TRAFFIC

- FLY LO FOR
  LOW DENSITY ATMOS
  HI SOC TRAFFIC

CAN SAVE 10 – 15 PERCENT
LOGISTICS COSTS

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IMPLICATIONS OF VARIABLE ALTITUDE STRATEGY

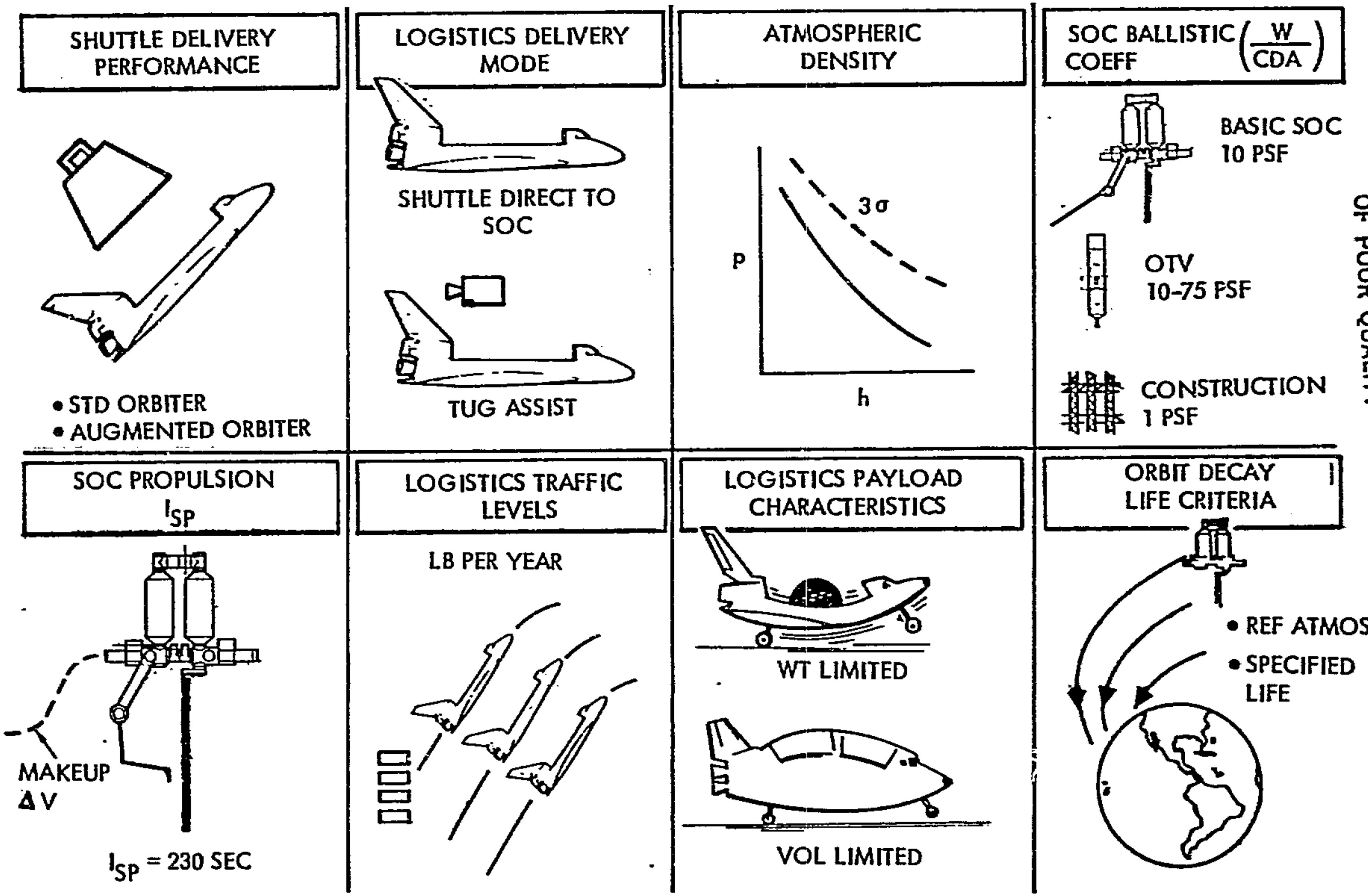
✓ • SIGNIFICANT SAVINGS IN SOC LOGISTICS COSTS

• FLY MOST LOGISTICS MISSIONS WITHOUT OMS

• COULD REQUIRE UP TO 50 PERCENT MORE SOC PROPELLANT DESIGN CAPACITY

• REQUIRES MISSION SUPPORT FOR VARIABLE EPHEMERIS
  - MCC/GROUND SUPPORT
  - LAUNCH OPPORTUNITY INTERVAL/RENDEZVOUS PHASING

SOC ORBIT ALTITUDE FACTORS



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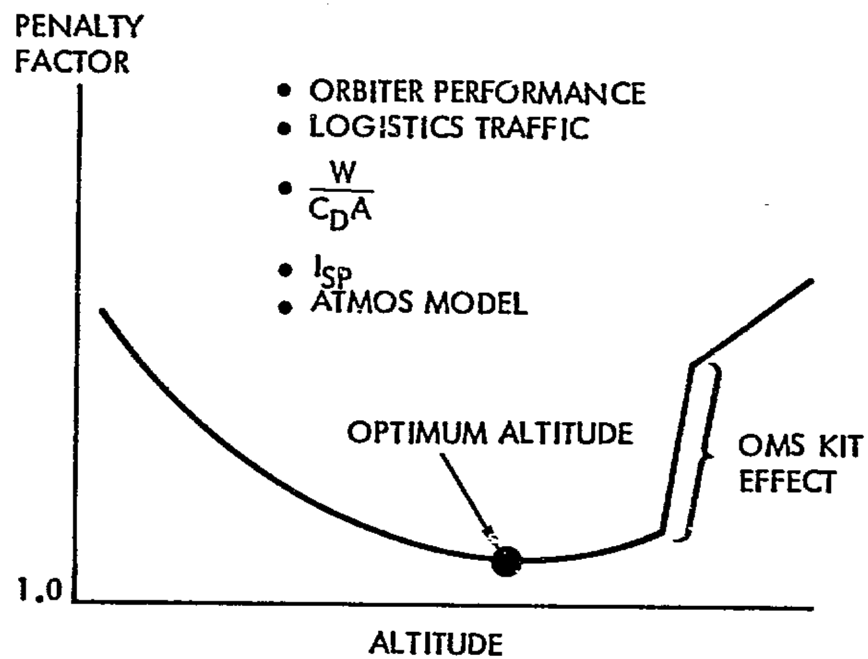
SOC ORBIT ALTITUDE OPTIMIZATION



PENALTY FACTOR DEFINITION

NORMALIZED TO NUMBER OF SHUTTLE FLTS REQUIRED TO DELIVER ASSUMED TRAFFIC TO 150 N MI

INCREMENT ABOVE 1.0 ACCOUNTS FOR SOC MAKEUP ΔV & SHUTTLE P/L DROP-OFF WITH ALTITUDE

$$\text{PENALTY FACTOR} = \frac{\left(1 + \dfrac{W_{MAKEUP}}{W_{TRAFFIC}}\right)}{\left(\dfrac{W_{STS_{ALT}}}{W_{STS_{150}}}\right)}$$

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ORBIT DECAY CONSIDERATIONS

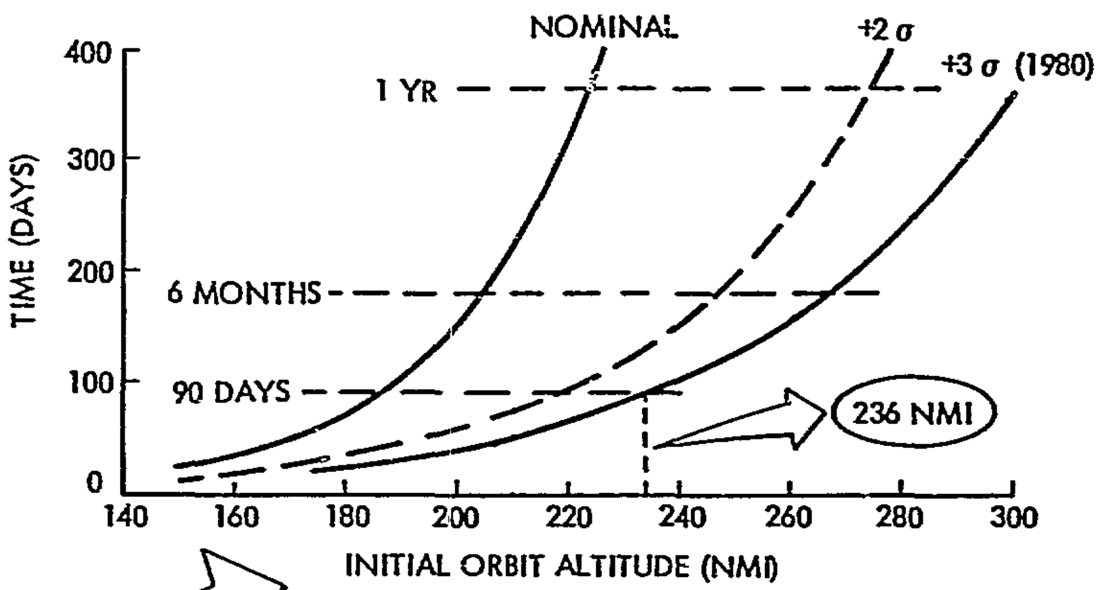
✓ SAFETY IS THE DRIVER

MAIN FACTORS:
- ATMOS MODEL
- SOC FAILURE
- ORBITER FLEET UNAVAIL

90-DAY DECAY WITH +3 σ ATMOS COVERS 3 LEVELS OF ADVERSITY

DECAY TIME TO 100 NMI

- PERIOD OF MAX SOLAR ACTIVITY (1990)
- $\frac{W}{C_D A} = 10$ PSF



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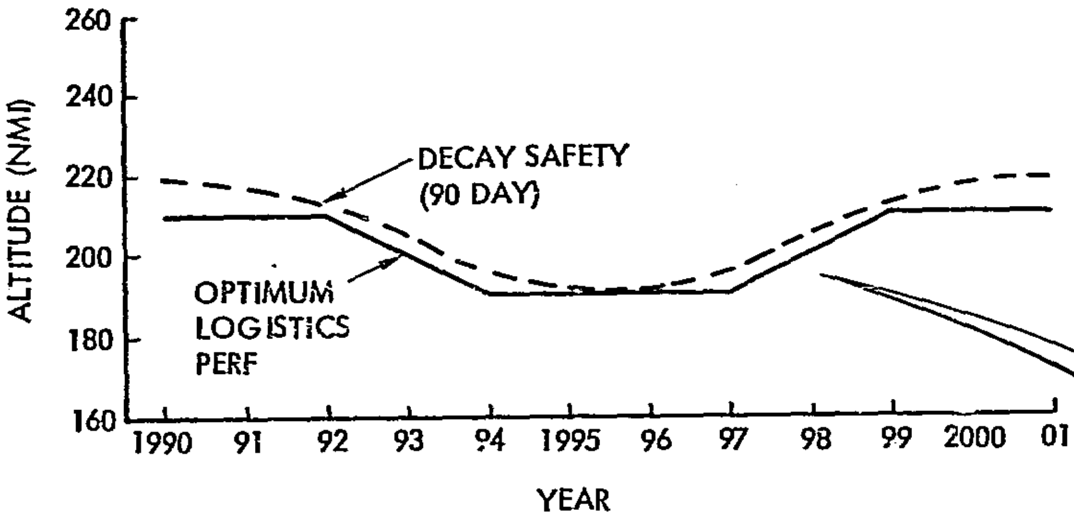
SOC OPERATIONAL ALTITUDE RANGE

- EXAMPLE ALTITUDE VARIATIONS
  STD SHUTTLE
  $\frac{W}{C_D A}$ = 10 PSF
  I_{SP} = 230 SEC
  LOGISTICS TRAFFIC = 2 SOC MASS/YR
  ATMOS = +2σ

ATMOS	ALT NMI		
	DECAY	OPTIMUM	
		LO TRAFF	HI TRAFF
3 σ MAX	236	210	210
NOMINAL MINIMUM	172	200	170



OPERATIONAL ALTITUDE RANGE

170 – 236 NMI

OMS NOT REQUIRED MOST OF THE TIME

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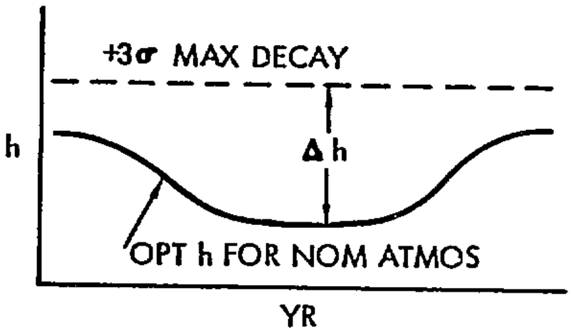
LOGISTICS SAVINGS WITH SOC VARIABLE ALT STRATEGY

This chart summarizes the typical range of savings in SOC logistics costs attainable with the variable altitude strategy. By "flying" SOC at the lowest safe altitude for the prevailing traffic and atmospheric conditions significant savings in logistics flights can be attained by taking advantage of the greater payload delivery capability of the Shuttle to the lower orbit altitudes.

For example, as shown in the upper right sector of the chart, the shuttle can deliver approximately 50,000 lbs to 236 n. mi altitude (the 3σ atmosphere, 90-day decay criteria altitude). This would be the lowest altitude permissable for operating SOC with a constant altitude strategy. Payloads above 60,000 lbs are attainable at altitudes of 200 n. mi. and below, which is the typical operating range for the variable altitude strategy. This is more than a 20 percent increase in payload capability which can be translated into 20 percent fewer logistics flights to handle the required logistics traffic. Even accounting for the increased SOC orbit makeup propellant required at the lower altitudes, the net savings in logistics flights is from 10 to 12 percent over the full-range of atmospheric variations throughout a typical 11-year solar cycle.

LOGISTICS SAVINGS WITH SOC VARIABLE ALT STRATEGY

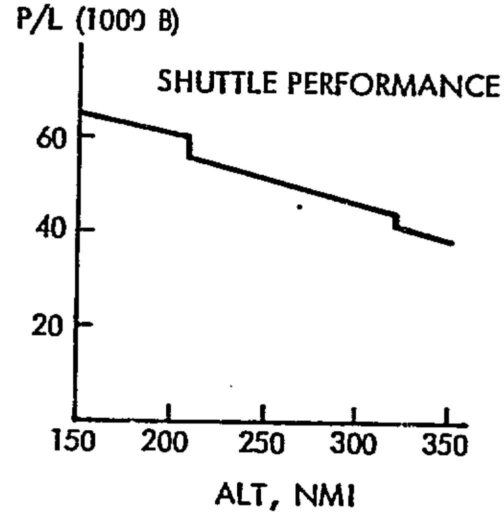


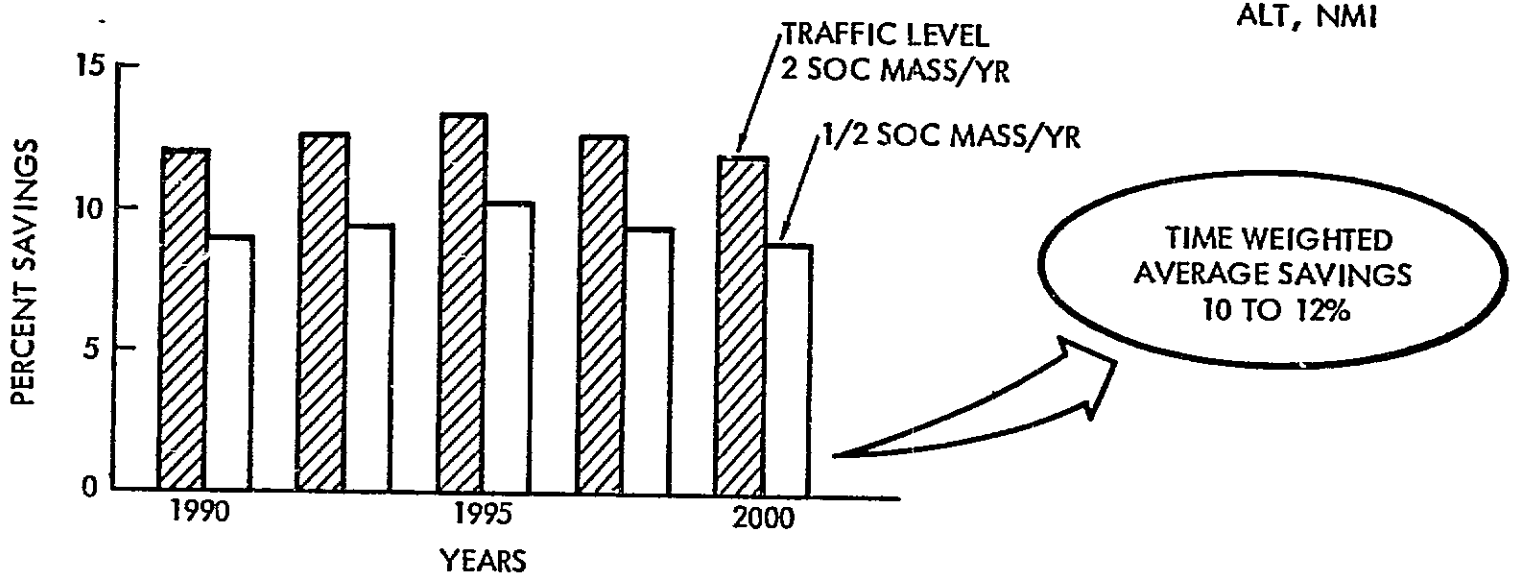
90 DAY DECAY

$\frac{W}{C_D A}$ = 10 PSF

I_{SP} = 230 SEC

STD SHUTTLE





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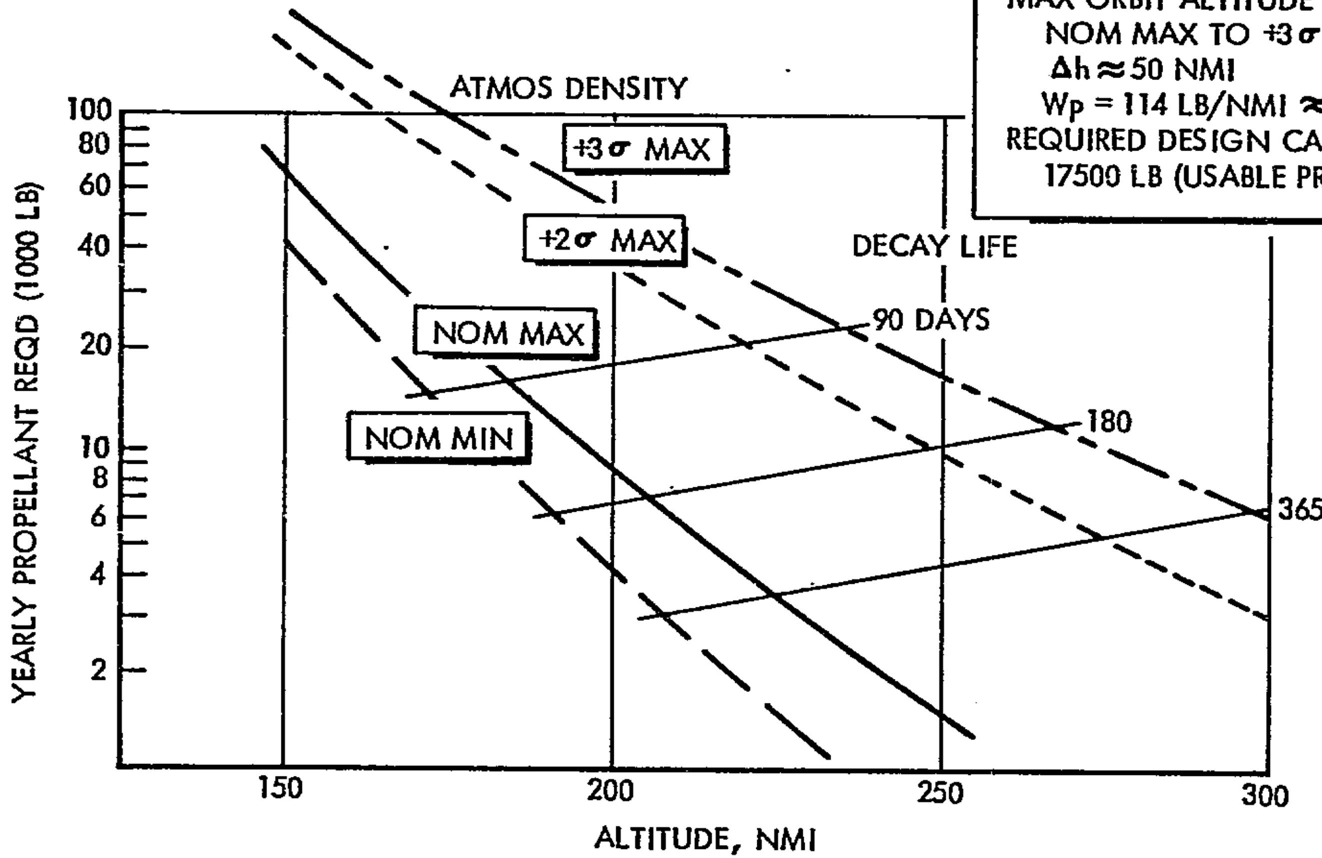
SOC PROPELLANT SIZING



BASIS FOR SIZING

BASIC REQ: 90 DAYS + 90 DAY CONTINGENCY
180 DAYS TOTAL
MAX ORBIT MAKEUP = 12000 LB
MAX ORBIT ALTITUDE CHANGE
NOM MAX TO +3σ MAX
$\Delta h \approx 50$ NMI
W_p = 114 LB/NMI ≈ 5500 LB
REQUIRED DESIGN CAPACITY
17500 LB (USABLE PROPELLANT)

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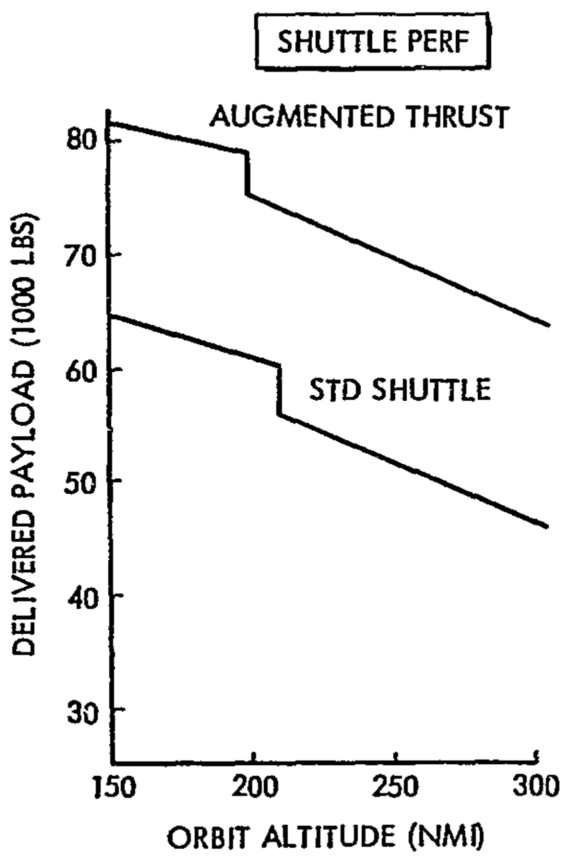
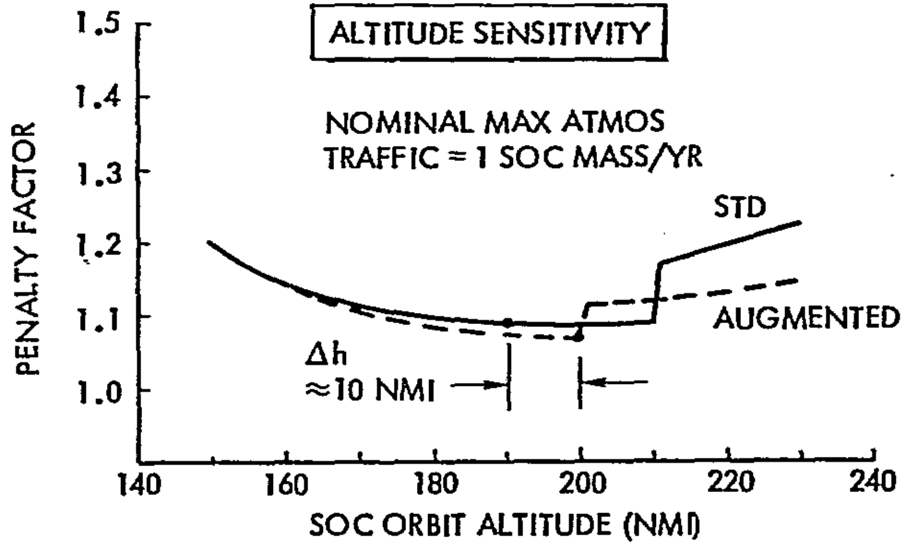
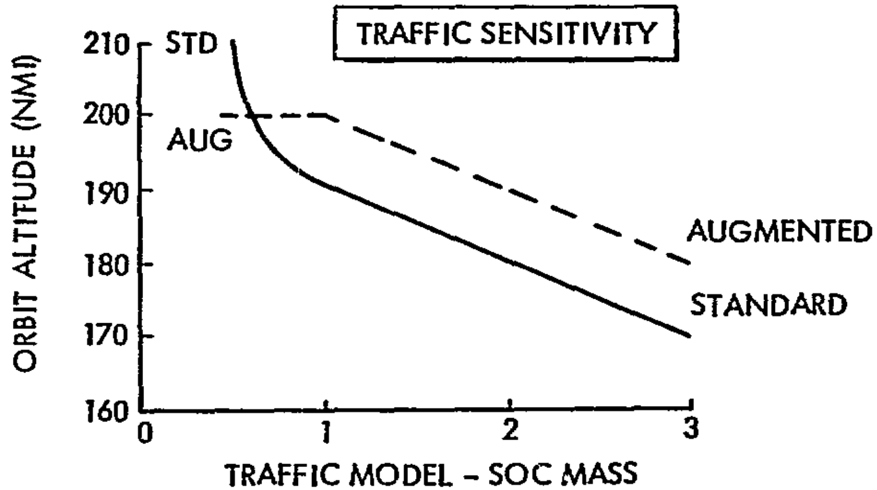
DELIVERY PERFORMANCE EFFECTS

STANDARD SHUTTLE CAN DO THE JOB







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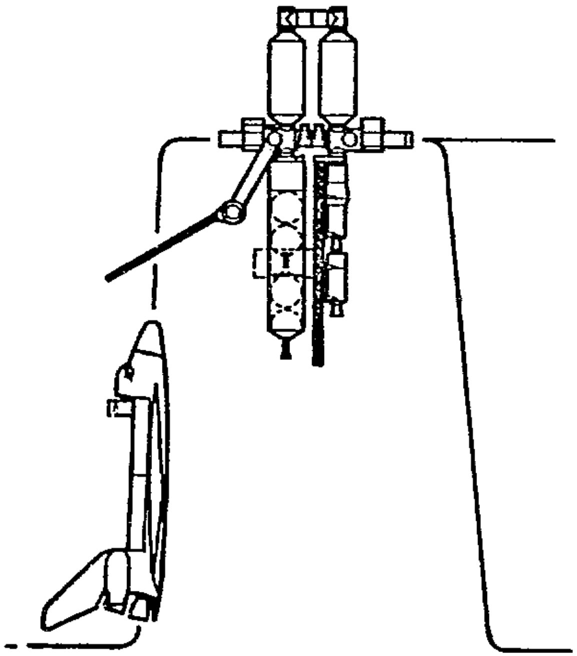
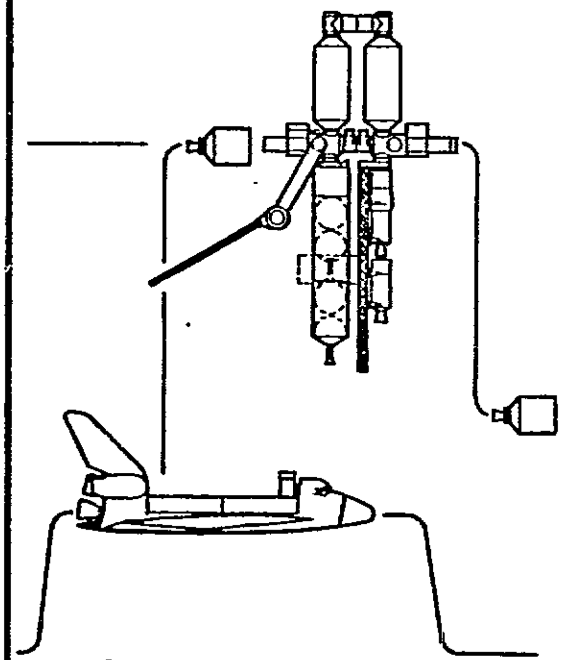
SOC LOGISTICS MODE OPTIONS

DIRECT SHUTTLE DELIVERY



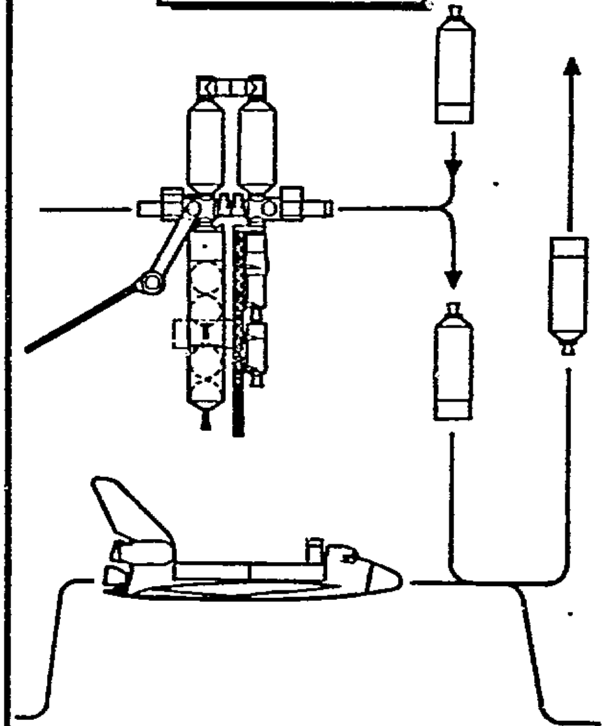
- SHUTTLE DELIVERS ALL LOGISTICS P/L's TO SOC

"TUG" ASSISTED DELIVERY



- SHUTTLE DELIVERS ALL LOGISTICS P/L's TO 150 NMI ALT
- "TUG" TRANSFERS P/L's TO SOC ALT
- "TUG" I_{SP} = 250 SEC

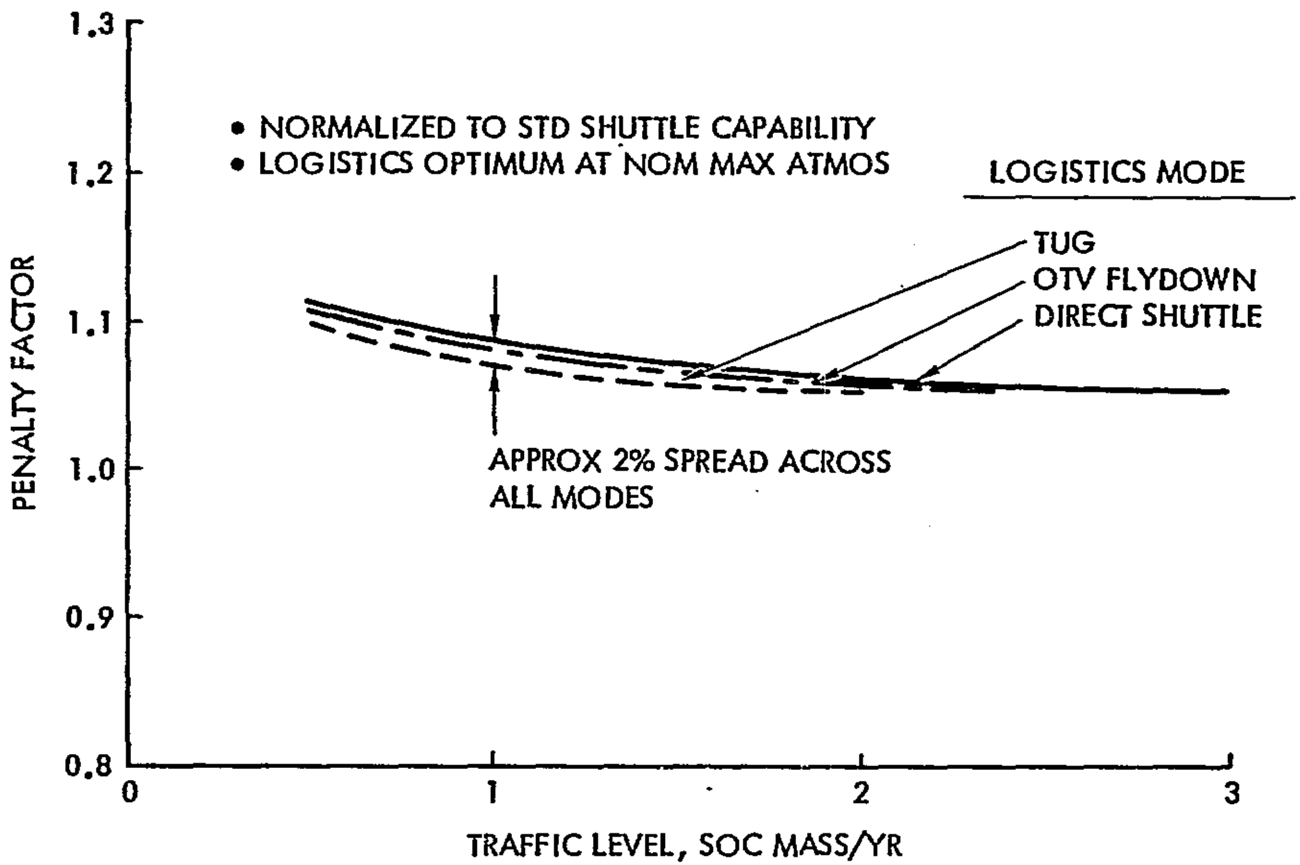
OTV FLY DOWN DELIVERY



- SHUTTLE DELIVERS MAKEUP ΔV TO SOC
- SHUTTLE DELIVERS OTV P/L's & PROPELLANT TO 150 NMI
- OTV FLYS TO GEO RETURNS TO SOC, THEN FLYS DOWN TO 150 NMI
- OTV I_{SP} = 460 SEC

DELIVERY MODES COMPARISON

DIRECT SHUTTLE DELIVERY THE WAY TO GO



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SOC ORBIT ALTITUDE WRAP-UP

✓ RECOMMEND VARIABLE ALTITUDE STRATEGY

- DRIVEN BY ORBIT DECAY OR LOGISTICS OPTIMUM
- SAVES LOGISTICS FLIGHTS
- FLY MOSTLY WITHOUT OMS

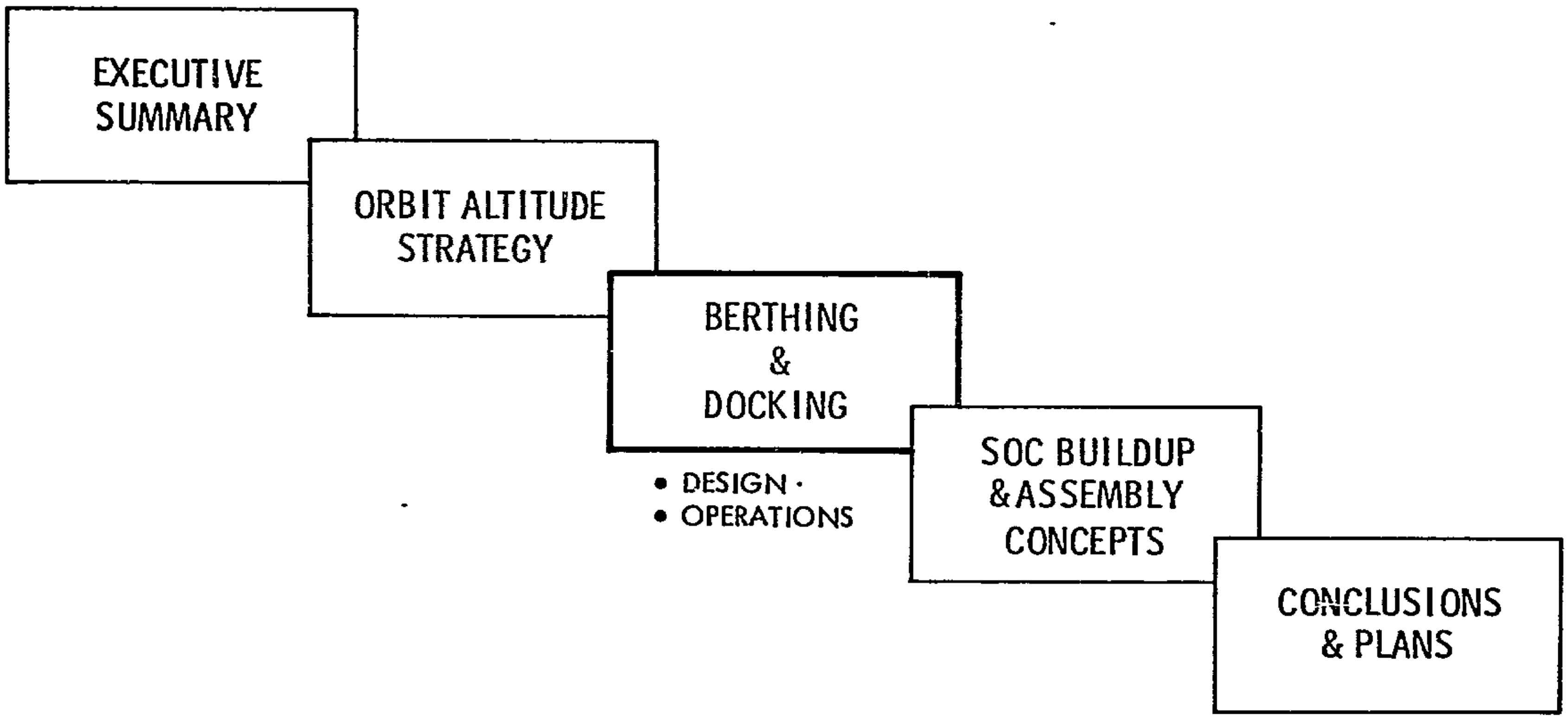
✓ STANDARD SHUTTLE CAN DO THE JOB

- "INSENSITIVE" TO ALTITUDE VARIATIONS NEAR THE OPTIMUM
- BOTH STD & AUGMENTED SHUTTLE ARE COMPATIBLE WITH SOC
- OMS TYPICALLY NOT REQUIRED. . . .
- ENHANCES ACCOMMODATION OF VOLUME LIMITED P/L's

✓ DIRECT SHUTTLE DELIVERY MODE APPEARS BEST

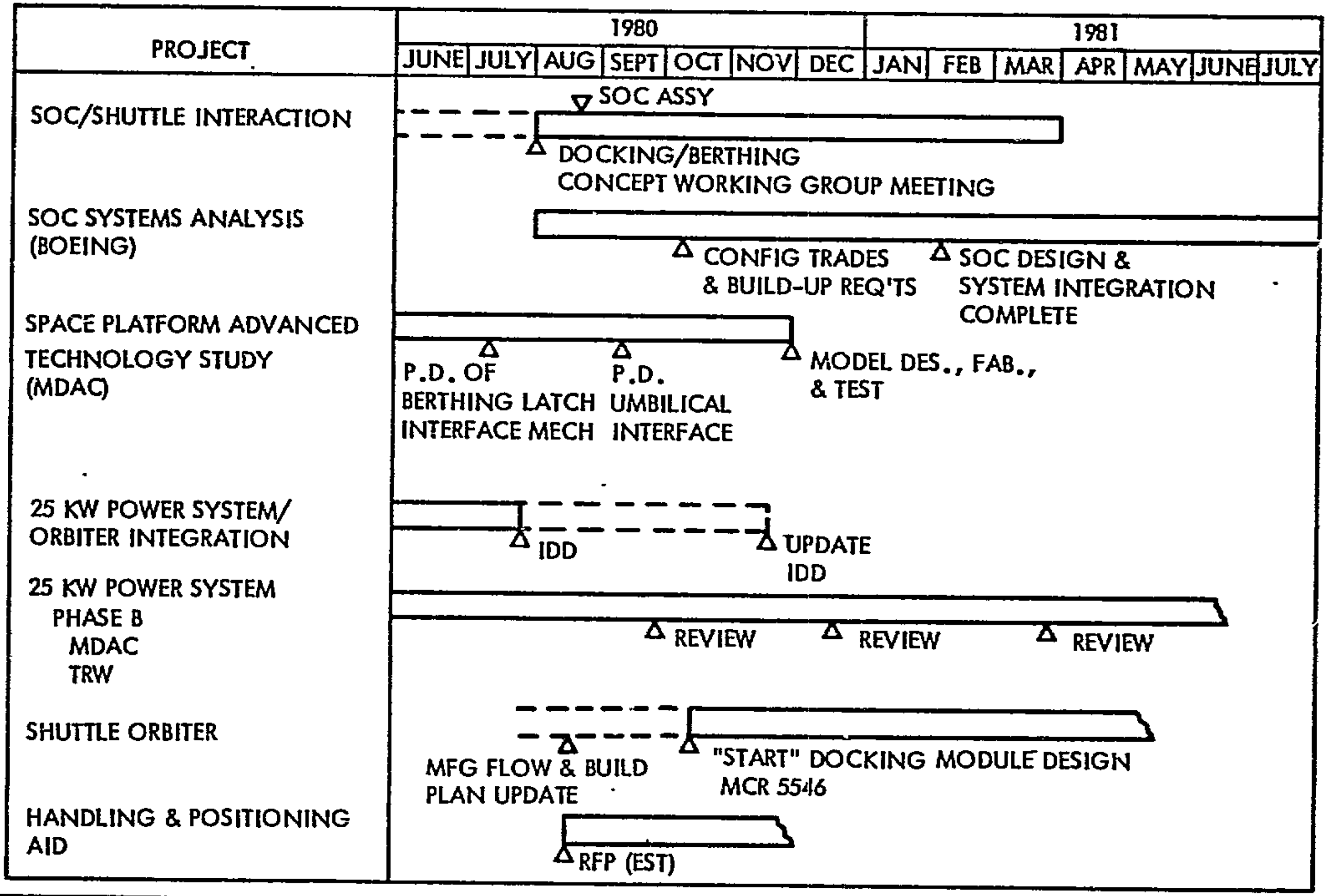
- NEGLIGIBLE LOGISTICS PERFORMANCE DIFFERENCE AMONG ALL MODES
- OPERATIONAL COMPLEXITIES WITH OTHER MODES

BRIEFING OUTLINE



PROJECT DOCKING/BERTHING RELATED MILESTONES

STATUS OF MCR & 25 KW POWER
SYSTEM DEMANDS EARLY DEFINITION
OF REQUIREMENTS AND STANDARDIZATION



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DOCKING/BERTHING WORKING GROUP ACTIVITIES

1980					
MAY	JUNE	JULY	AUG	SEPT	OCT

14 △ INTRO BRIEFING AT JSC

NEED TO ESTABLISH A STANDARIZED DOCKING CONCEPT
- JSC DOCKING WORKING GROUP ESTABLISHED

△ 29 ESTABLISHED ROCKWELL INTERNATIONAL DOCKING WORKING GROUP

MEMBERS:

A.J.STEFAN – CHAIRMAN
E. KATZ – MANAGER – SOC STUDY
H. MYERS – SOC SYSTEMS ENGR
D. DENISON – PROJ MANAGER 25 KW INTEGRATION
D. TAAL – SHUTTLE PROJ OFFICE DOCKING MODULE
T. APPLEBERRY – SHUTTLE ADVANCED PROJECTS
E. DAZZO – SHUTTLE SIMULATION
J. MANSFIELD – PAYLOAD INTEGRATION
G. FRAZER – STS BUSINESS DEVELOPMENT

11 △ SECOND MEETING OF ROCKWELL INTERNATIONAL WORKING GROUP

△ 30 COMBINED MEETING OF ROCKWELL INTERNATIONAL & JSC WORKING GROUPS AT JSC
- DOCKING CONCEPT & PRELIMINARY REQUIREMENTS OF A STANDARDIZED CONCEPT SUBMITTED

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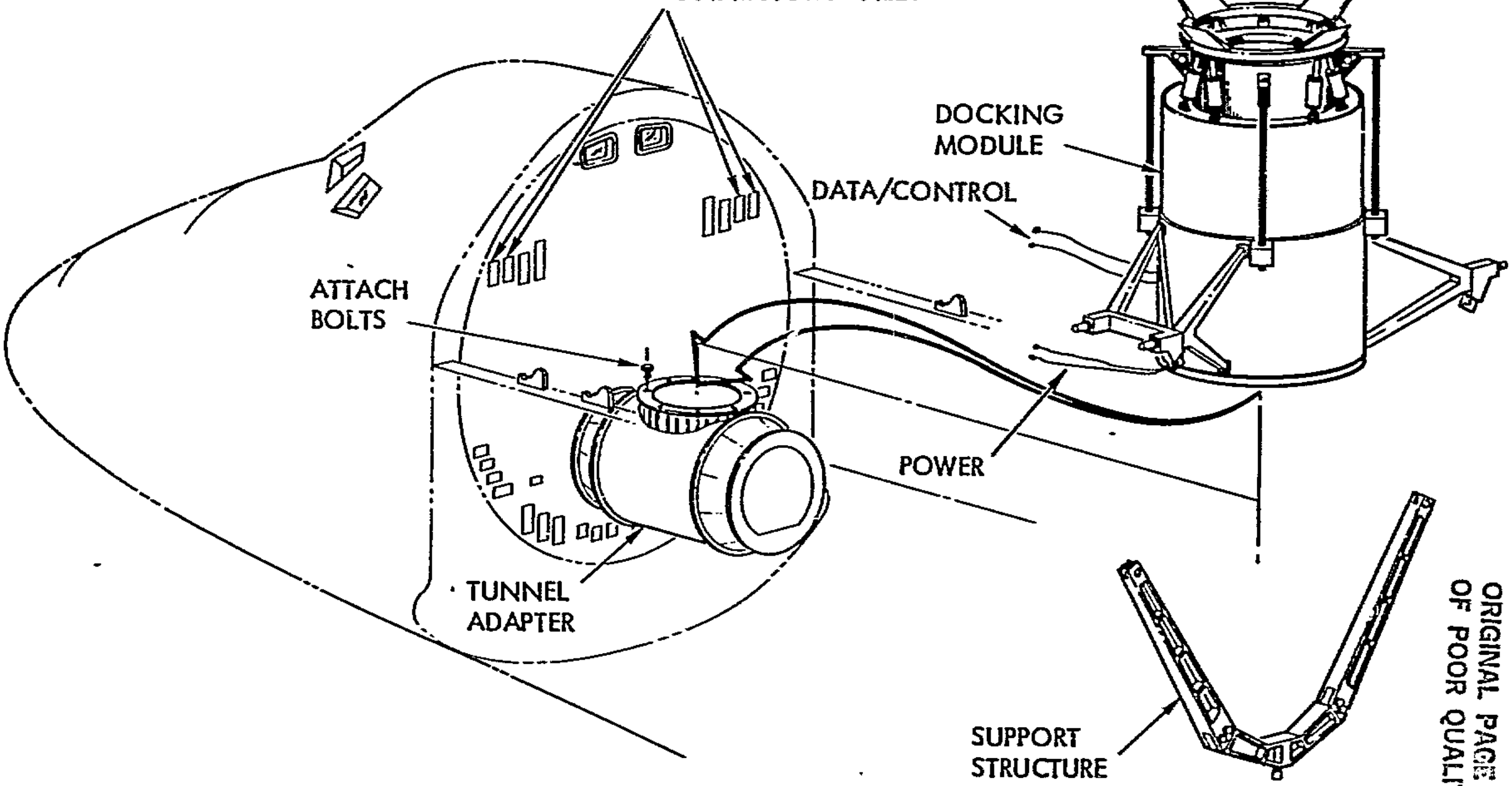
DOCKING MODULE CONCEPT

DOCKING MODULE IS DESIGNED FOR EASY CHANGEOUT - LIKE CARGO



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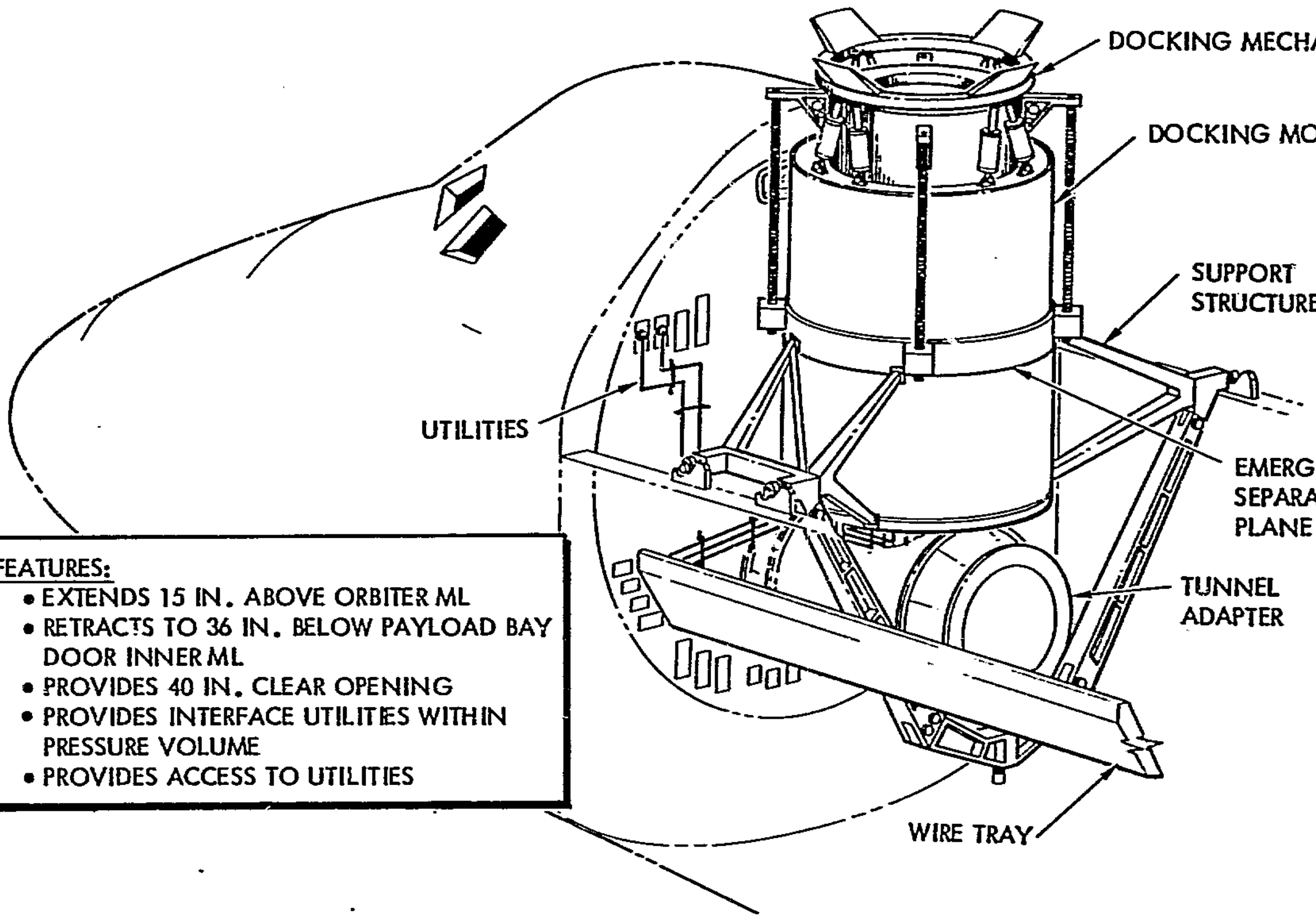
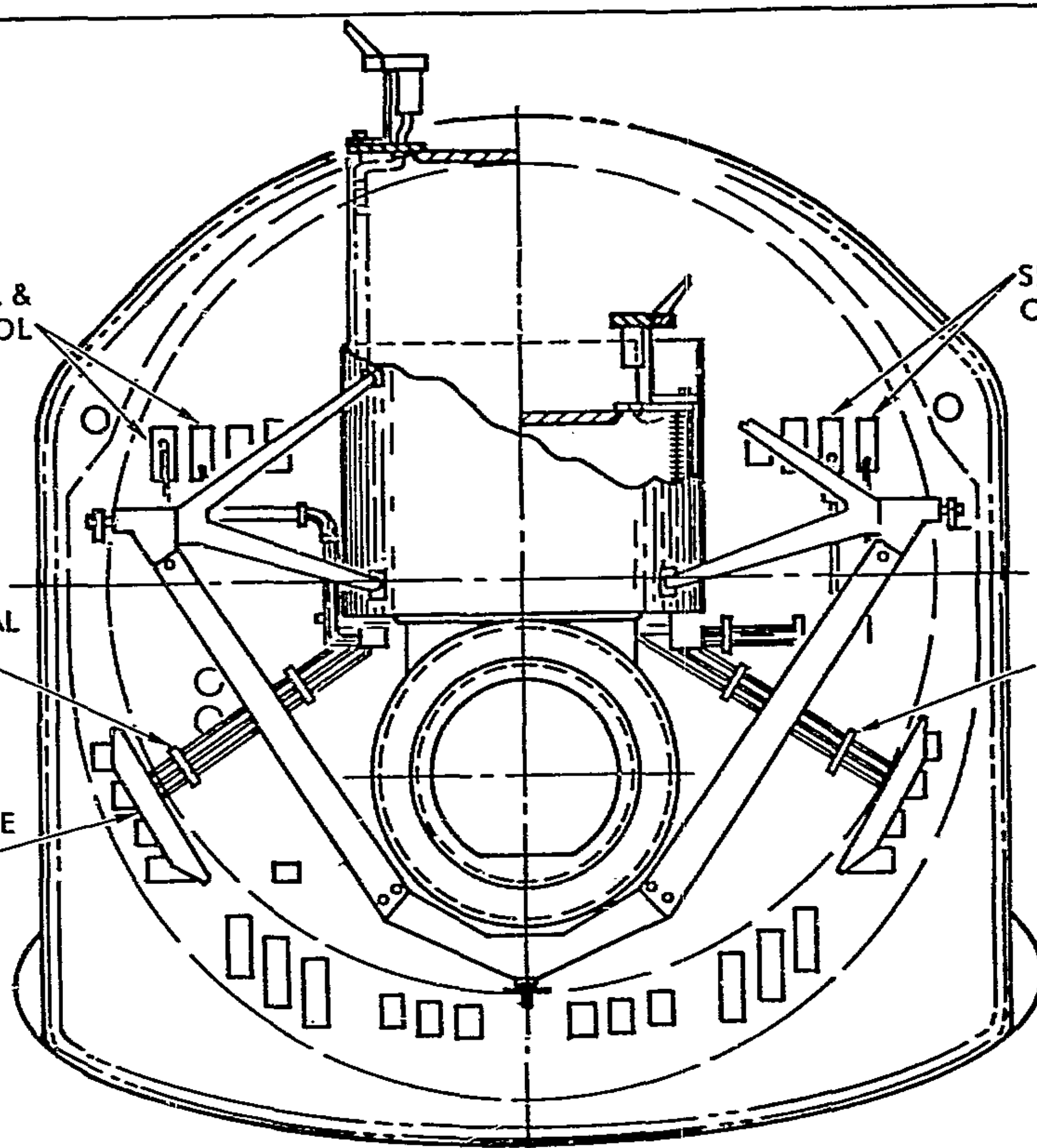
DOCKING MODULE FEATURES



FEATURES:

- EXTENDS 15 IN. ABOVE ORBITER ML
- RETRACTS TO 36 IN. BELOW PAYLOAD BAY DOOR INNER ML
- PROVIDES 40 IN. CLEAR OPENING
- PROVIDES INTERFACE UTILITIES WITHIN PRESSURE VOLUME
- PROVIDES ACCESS TO UTILITIES

UTILITIES INTERFACE ROUTING



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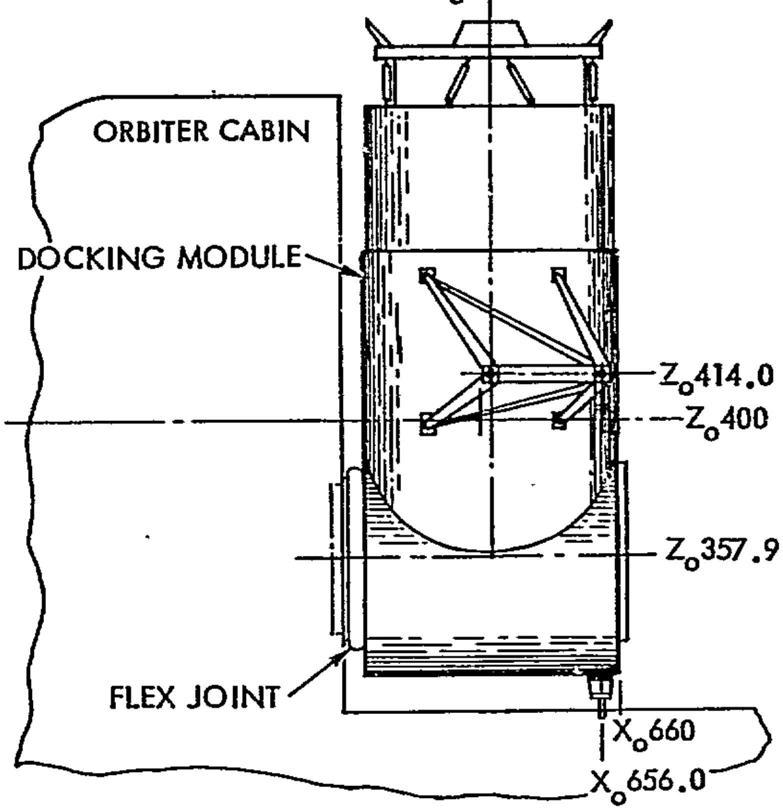
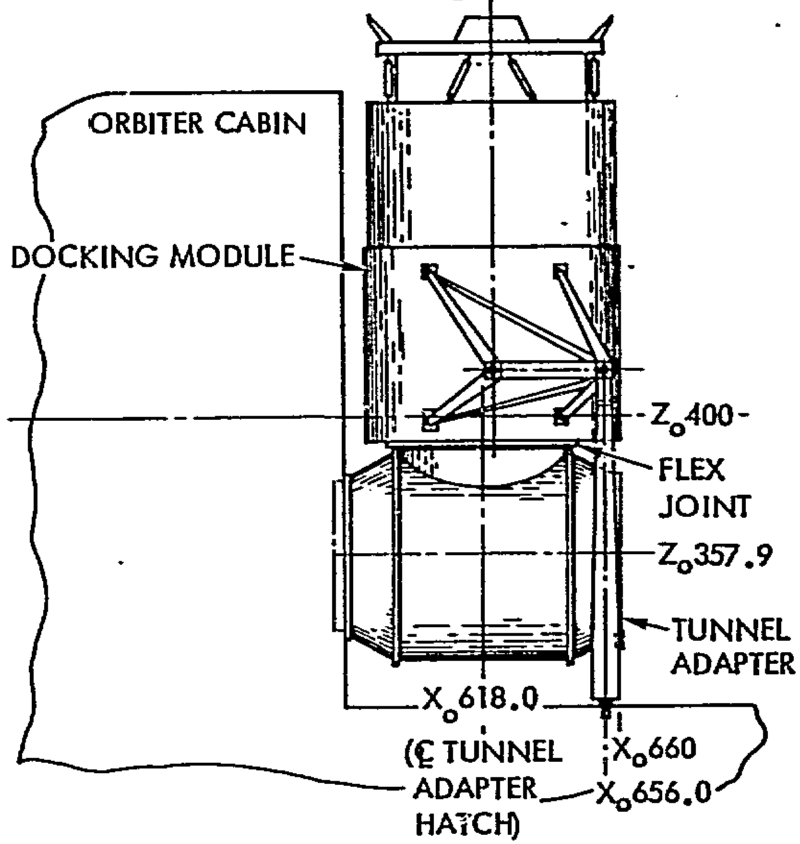
DOCKING MODULE CONFIGURATION OPTIONS

COMPLETE SINGLE ITEM



UTILIZATION OF TUNNEL ADAPTER



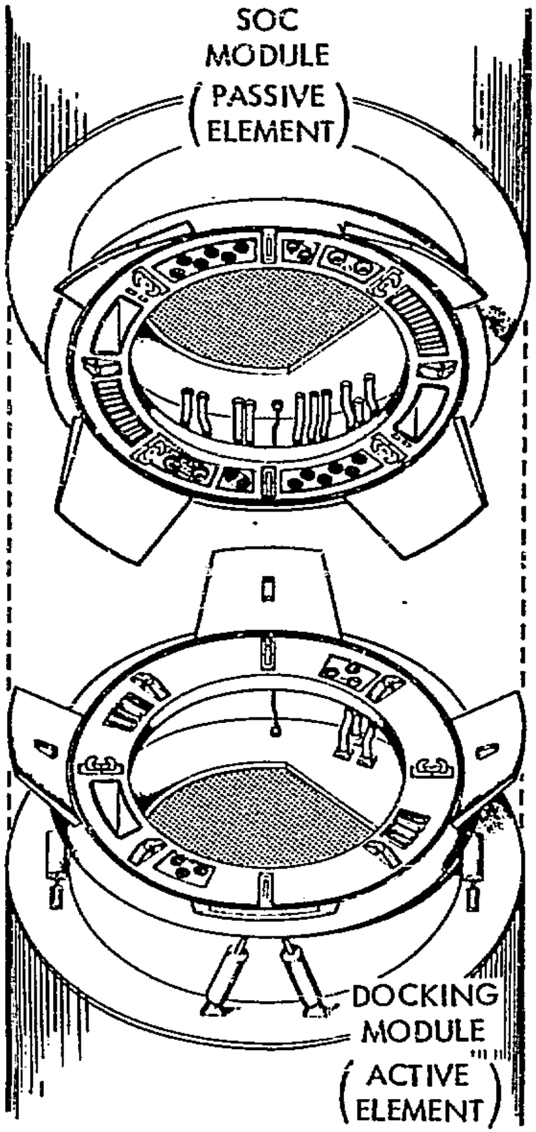
RETAINS INSTALLATION OF:

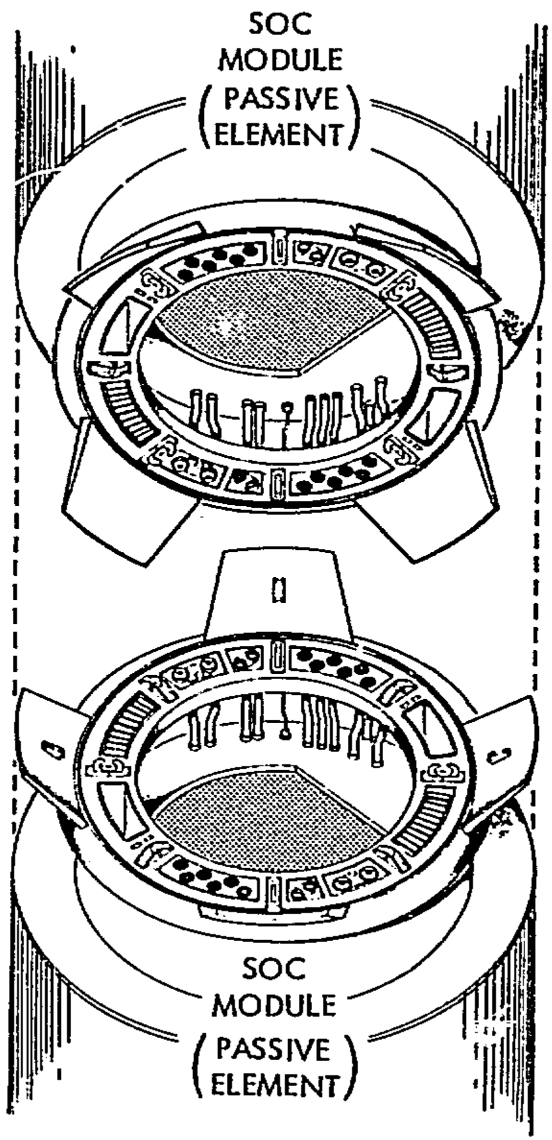
1. TUNNEL ADAPTER
2. ARS
3. ELECTRICAL

MATING ARRANGEMENTS

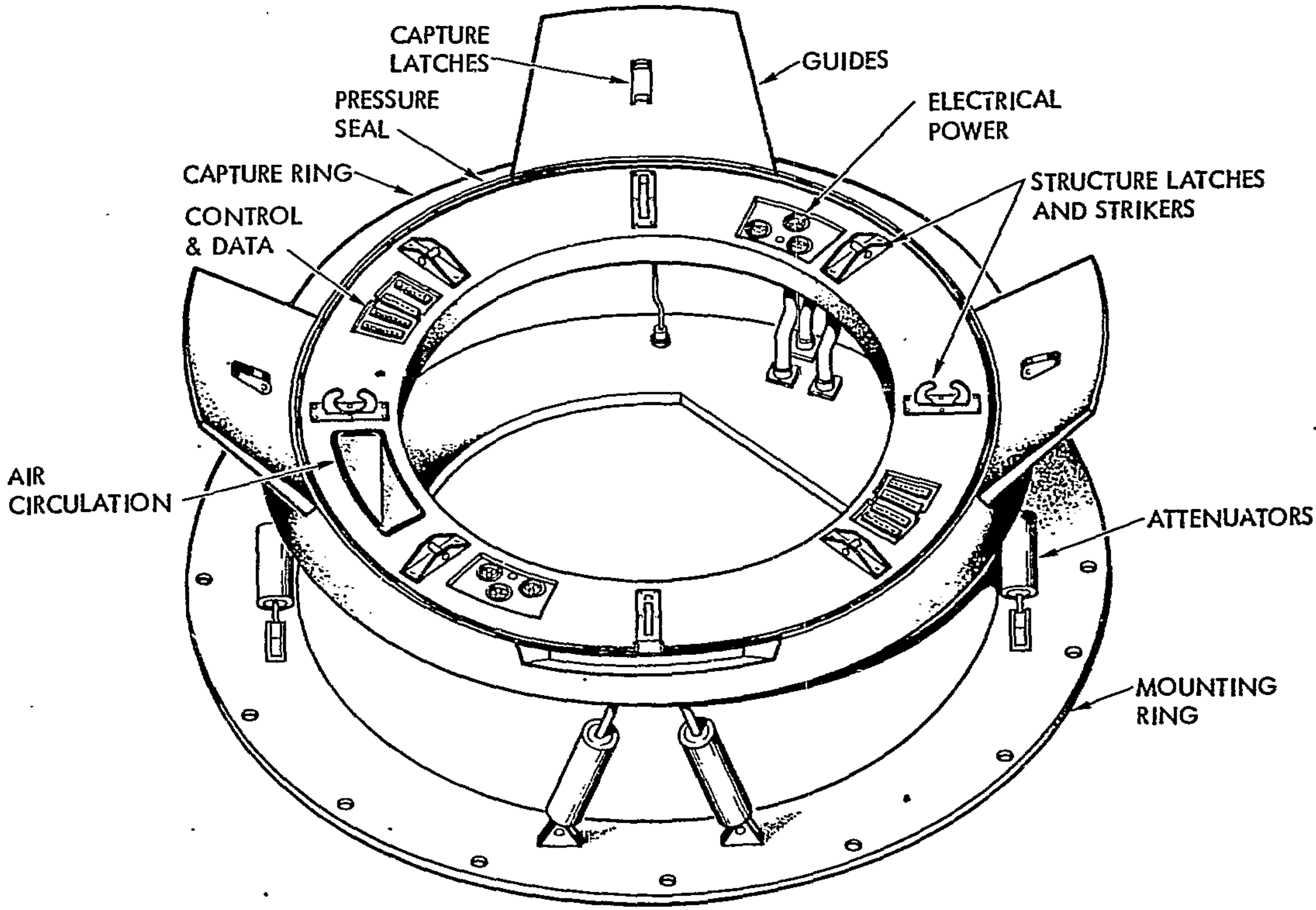
The docking modeule interface was designed for universal usage. In other words, it was designed to berth with any SOC port. Sufficient commonality and standardization features, such as latches, guides and utilities, were retained for the SOC module to SOC module interface. The size and quantity of utility connections are estimates which were based on a previous Rockwell Space Station study. A more detailed look at both types of interfaces is presented in the next few charts.

MATING ARRANGEMENTS

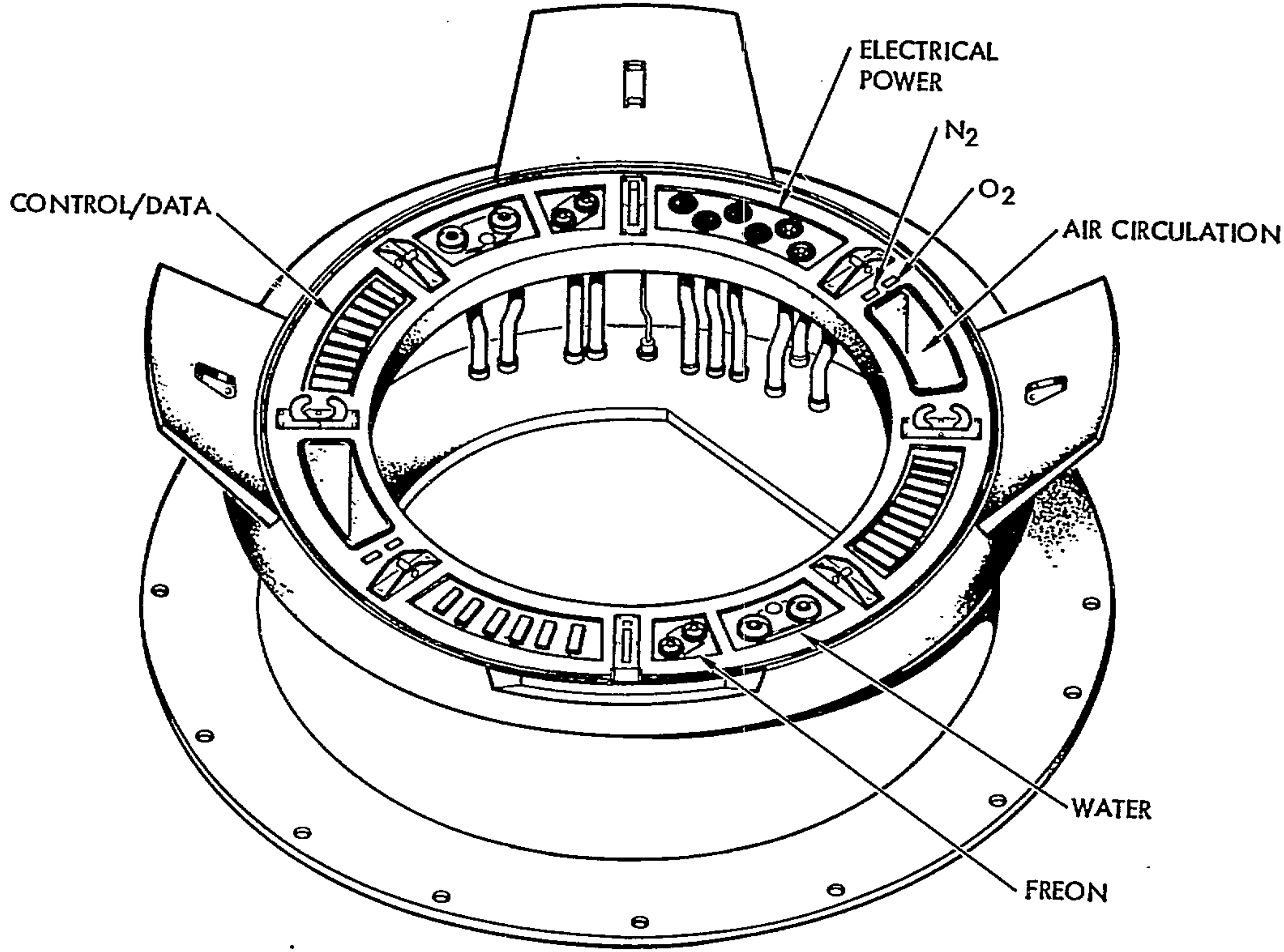




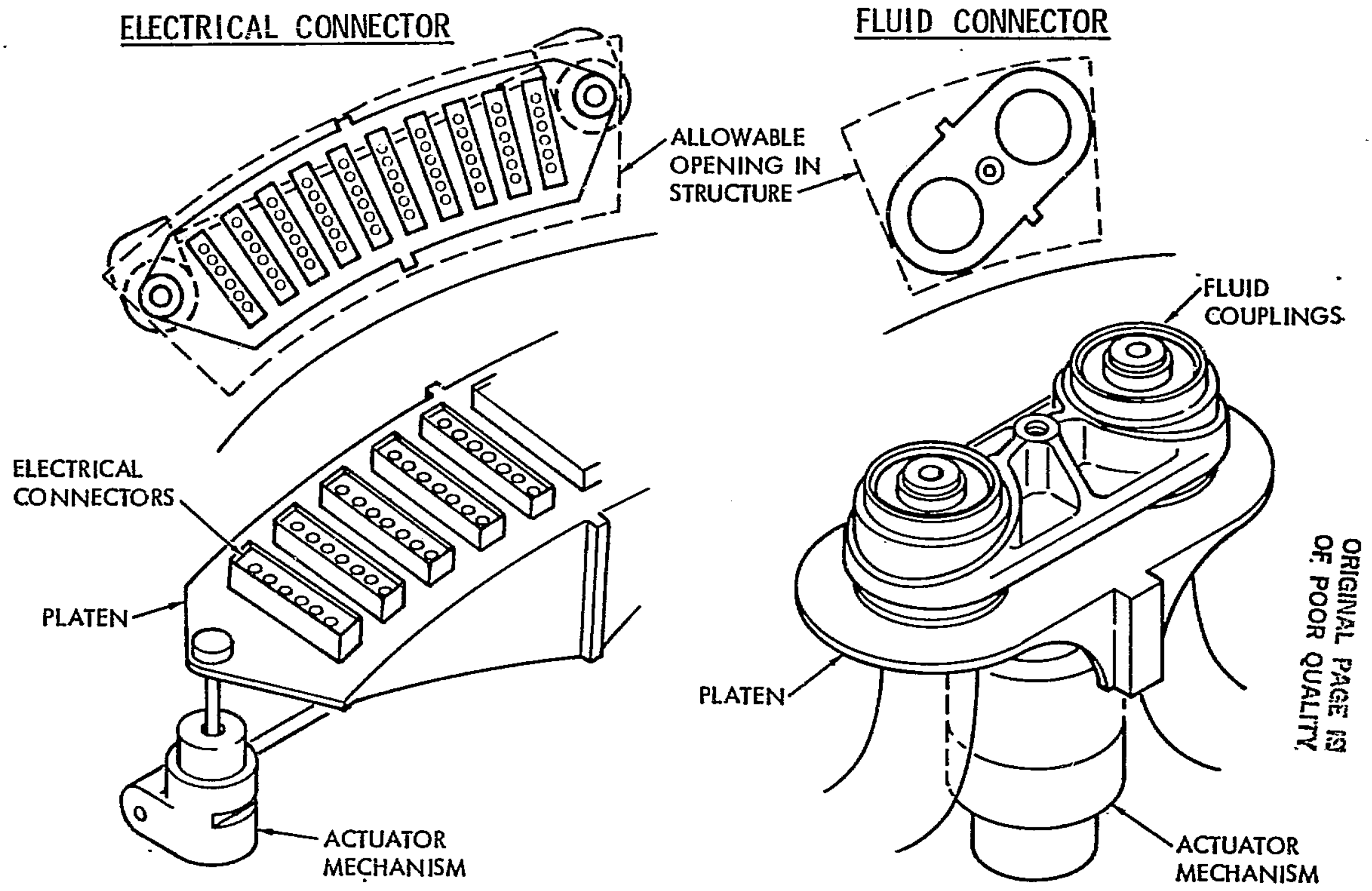
ORBITER TO SOC INTERFACE



SOC TO SOC INTERFACE



REMOTE ACTUATED INTERFACE CONNECTORS CONCEPTS



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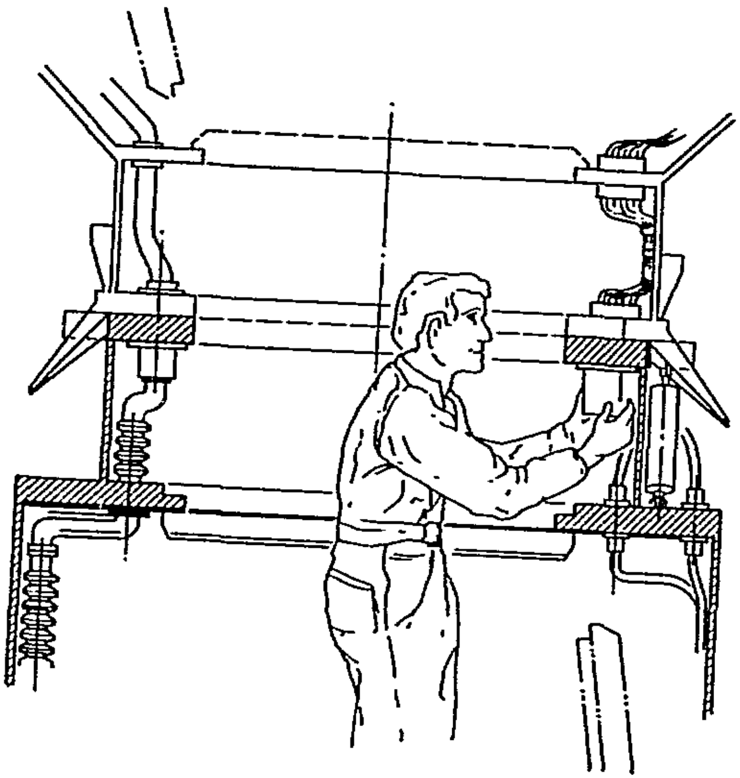
UTILITIES INTERFACE ACCESS

To investigate the issue of accessibility for utilities maintenance, we have completed a preliminary layout that confirmed that all utility interfaces are accessible. This conclusion applies to nominal maintenance operations by a shirt-sleeve astronaut and to contingency maintenance operations by a pressure suited astronaut. Two features of the docking module design contributed to the accessibility situation considerably, the placement of the attenuators outside the pressure volume which kept them close to the main load path, and the outward pointing guide petals. Inward pointing guide petals were considered but were not selected because they were not as amenable to maintenance accessibility as the outward pointing guide petals.

UTILITIES INTERFACE ACCESS

NOMINAL MAINTENANCE



CONTINGENCY MAINTENANCE

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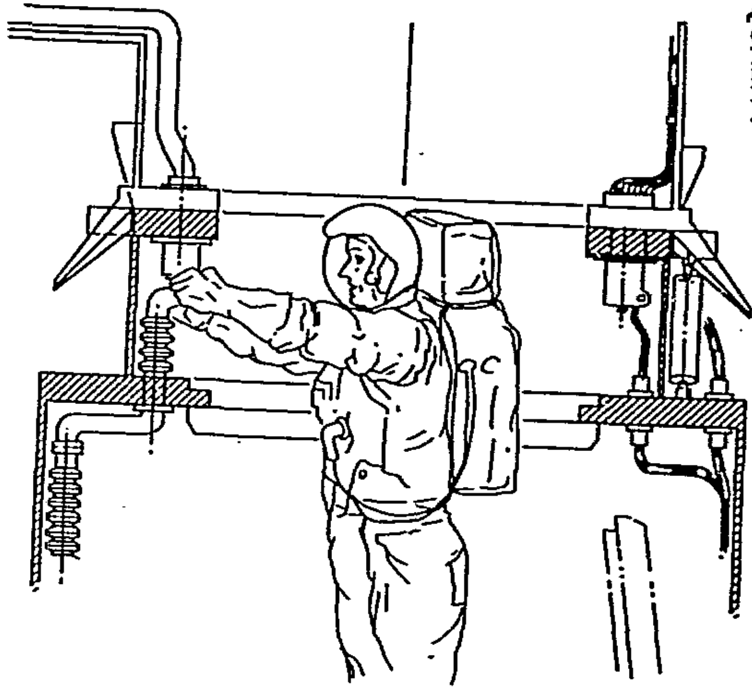
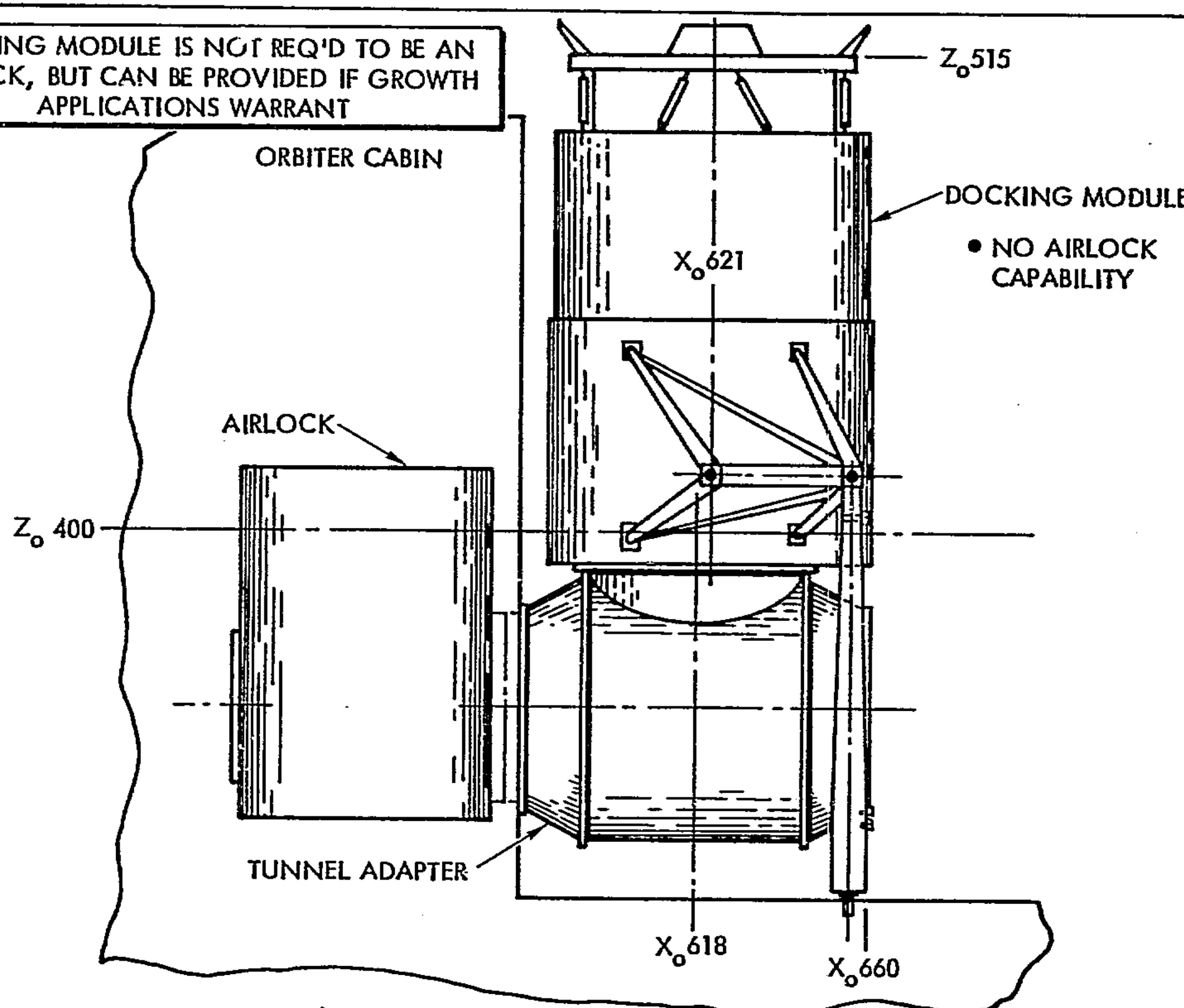


NOMINAL ORBITER ARRANGEMENT CONCEPT

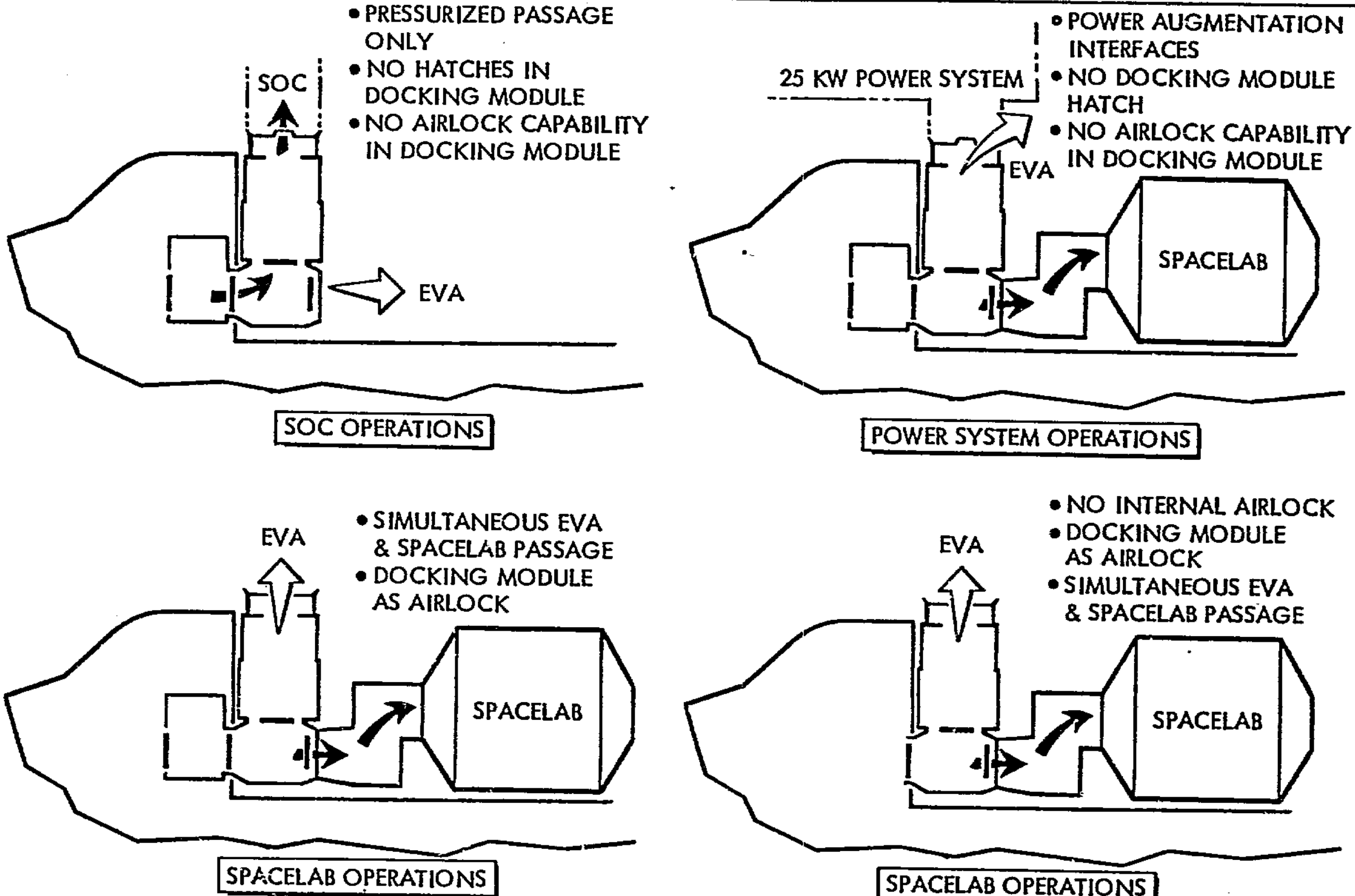
DOCKING MODULE IS NOT REQ'D TO BE AN AIRLOCK, BUT CAN BE PROVIDED IF GROWTH APPLICATIONS WARRANT



EVA OPTIONS

This chart illustrates that the proposed docking module concept, if provided with an airlock capability, can provide EVA passage with any combination of payloads.

EVA OPTIONS



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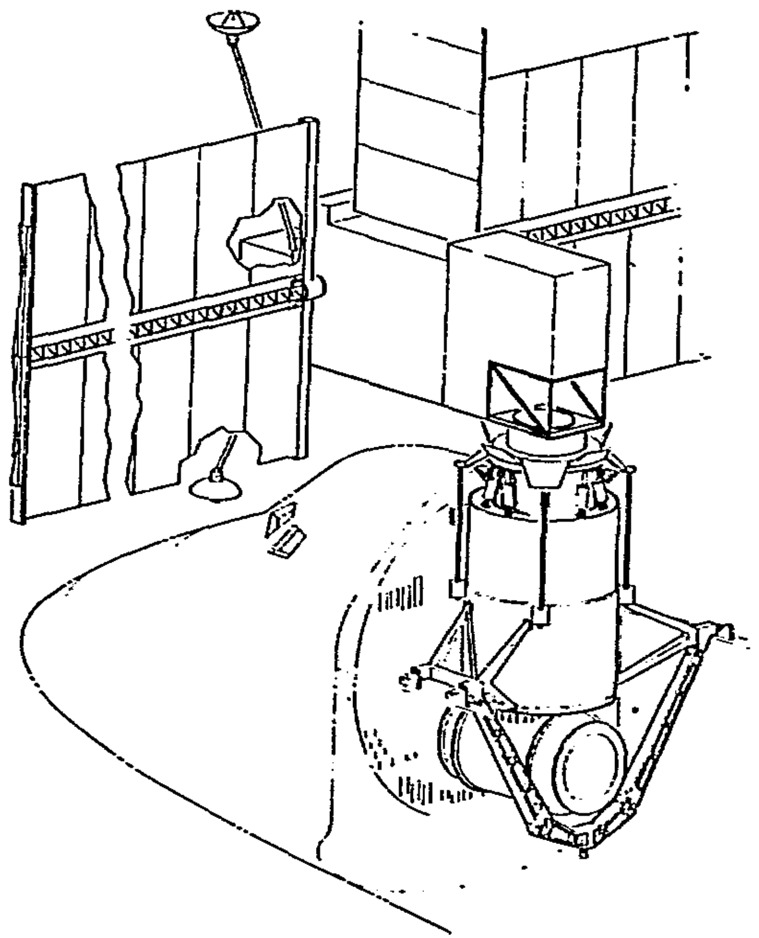
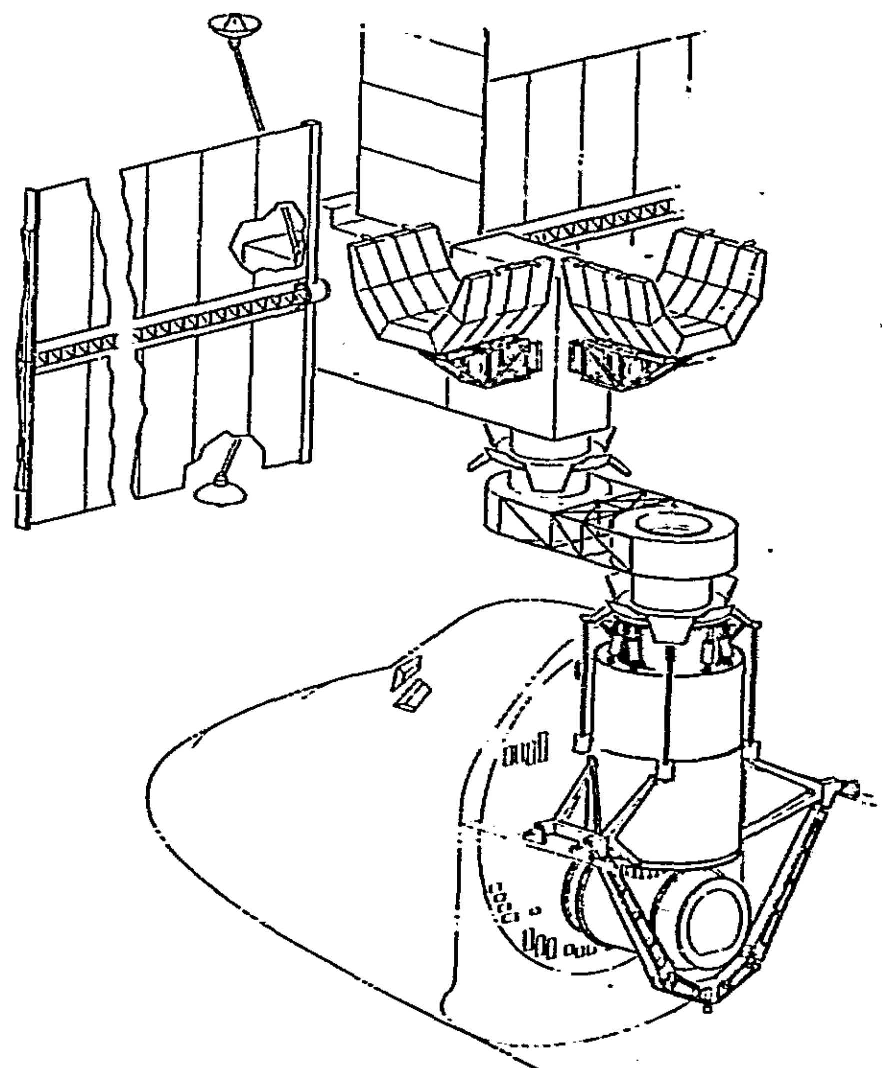
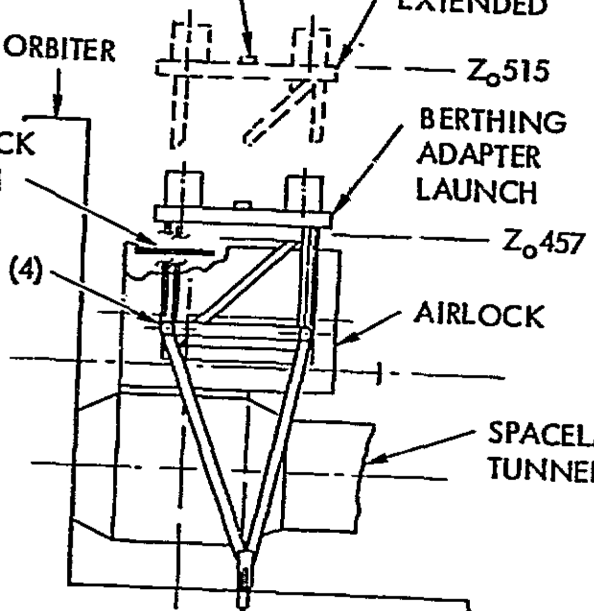
EVA DESIGN IMPLICATIONS FOR UNMANNED SYSTEMS



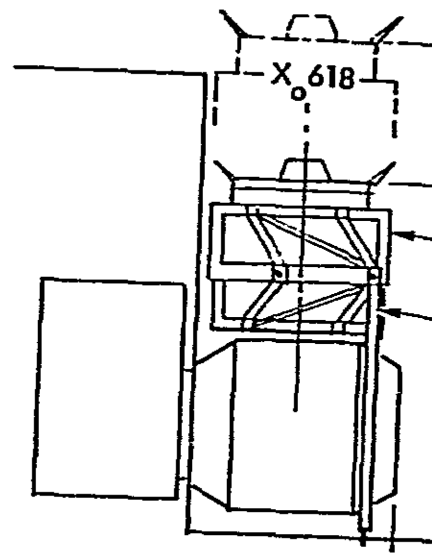


ALTERNATIVE DOCKING SYSTEM FOR UNMANNED OPERATIONS

POWER SYSTEM REFERENCE CONFIGURATION



DOCKING MODULE CONCEPT CAPABILITY



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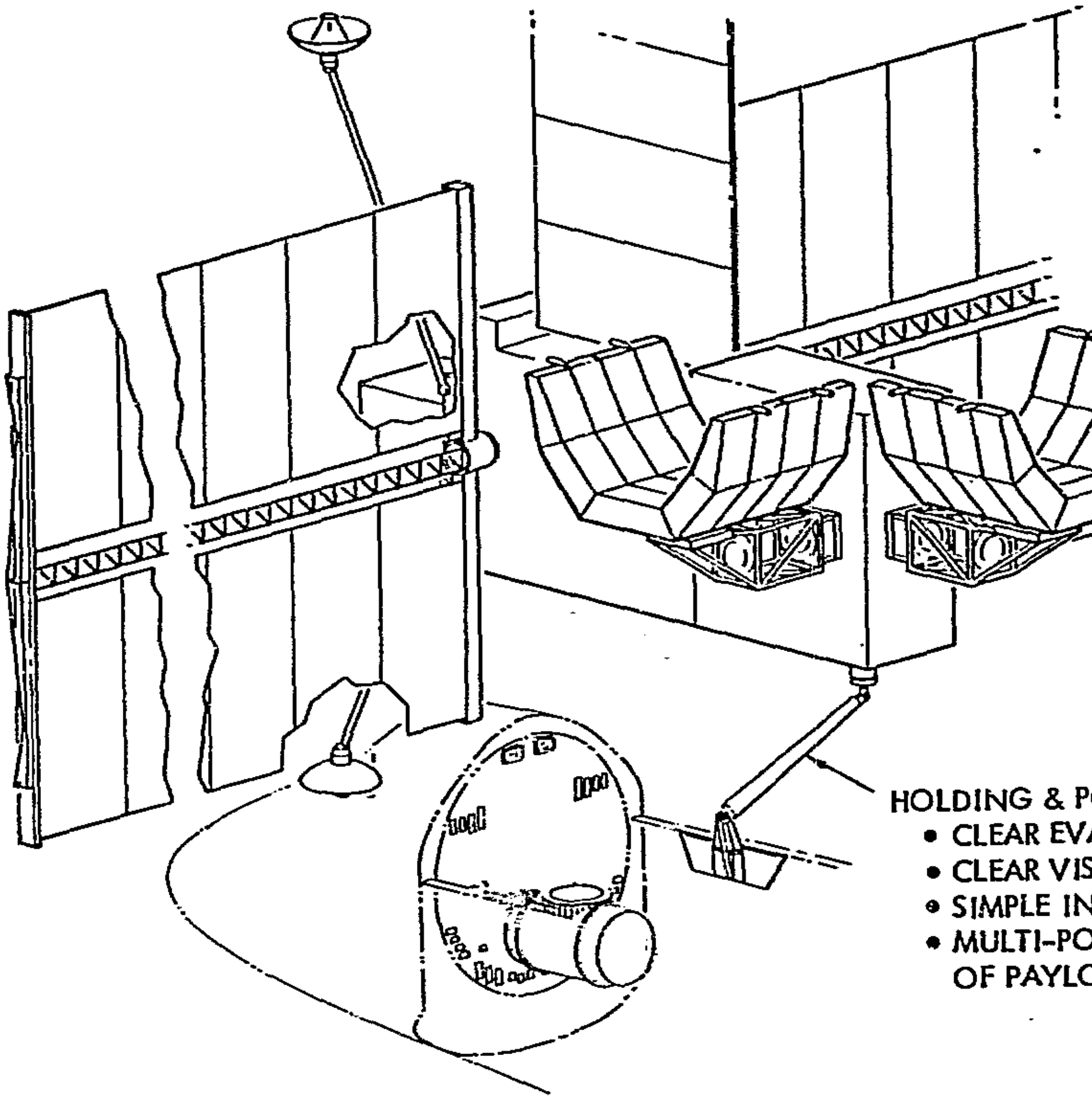
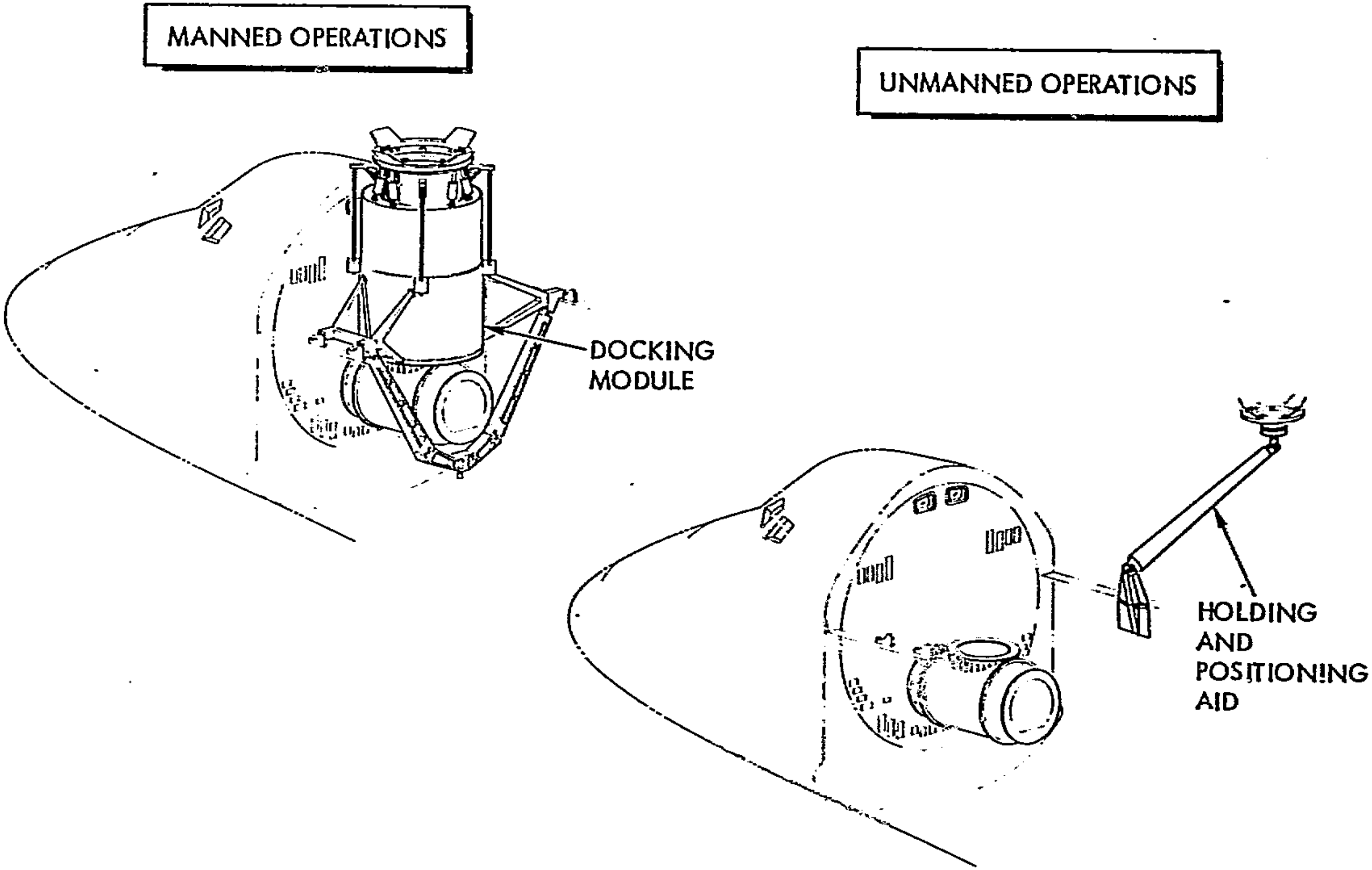
RECOMMENDED ALTERNATIVE CONCEPT FOR UNMANNED PAYLOADS



HOLDING & POSITIONING AID
- CLEAR EVA ACCESS
- CLEAR VISION FROM AFT WINDOWS
- SIMPLE INSTALLATION OF HAPA
- MULTI-POSITIONING/ORIENTATION OF PAYLOADS

CONFIGURATION SUMMARY



DOCKING MODULE PRELIMINARY REQUIREMENTS

As a consequence of the SOC/Shuttle Interaction study and Rockwell's participation in the Docking/Berthing Working Group, we have generated a set of preliminary design requirements for a standardized docking module. These requirements were submitted to the NASA Docking/Berthing Working Group and are presently being reviewed.

DOCKING MODULE PRELIMINARY REQUIREMENTS

• UTILITIES INTERFACES

- ALL UTILITIES INTERFACES SHALL BE LOCATED WITHIN THE PRESSURE SEALED INTERFACE AND WILL BE REMOTELY ACTIVATED.
- ALL OF THE UTILITIES INTERFACES WILL BE ACCESSIBLE TO THE CREW FROM WITHIN THE PRESSURIZED ENVIRONMENT.
- ANY SERVI AREA WILL
- THE UTILI ARE TBD.
- THE LOCAT ARE TBD.

• EXTENSION DEVICE

- EXTENSION TUNNEL AND DOCKING MECHANISM WHEN RETRACTED WILL PROVIDE EVA CLEARANCE WITH THE PAYLOAD DOORS CLOSED (MINIMUM CLEARANCE 36" FROM DOCKING INTERFACE -Zo 457).
- EXTENSION TUNNEL WITH DOCKING MECHANISM WILL EXTEND 15" BEYOND ORBITER MOLDLINE (DOCKING INTERFACE AT Zo 515).
- THE FIXED STRUCTURE OF THE EXTENSION DEVICE WILL BE SUPPORTED FROM THE ORBITER PAYLOAD BAY LONGERON BRIDGE STRUCTURE AND CENTERLINE KEEL STRUCTURE.
- ACCOMMODATION OF C
- A FLEXIBLE, PRESSU AND THE TUNNEL ADA TUNNEL ADAPTER.
- ONE HINGED HATCH W TUNNEL.
- AN EMERGENCY SEPAI DOOR CLOSURE IS PC CABIN PRESSURE, UN
- AIRLOCK CAPABILITI CONFIGURATION.
- A MINIMUM CLEAR PA OR EXTENDED ARRANG
- THE EXTENSION DEVI AND Xo 660.

• DOCKING MECHANISM

- THE DOCKING MECHANISM SYSTEM SHALL BE ANDROGYNOUS AND ALLOW DOCKING AT 90° ALIGNMENT INCREMENTS.
- ALL DOCKING SYSTEM HARDWARE EXCEPT THE ATTENUATORS SHALL BE LOCATED WITHIN THE PRESSURE SEALED INTERFACE AND BE ACCESSIBLE TO THE CREW FROM WITHIN THE PRESSURIZED ENVIRONMENT. THE IMPACT ATTENUATORS WILL BE LOCATED OUTSIDE OF THE PRESSURIZED INTERFACE AREA.
- A 1M CLEAR OPENING WILL BE MAINTAINED THROUGH THE DOCKING MECHANISM AT ALL TIMES.
- THE GUIDE PETALS WILL BE ORIENTED ALONG THE ORBITER COORDINATE AXIS.
- DOCKING - DESIGN IMPACT CONDITIONS

AXIAL CLOSING VELOCITY	-	0.05 - 0.50 FT/SEC
LATERAL VELOCITY	-	$\leq$0.2 FT/SEC
ANGULAR VELOCITY	-	1.0 DEG/SEC (About any axis)
LATERAL MISALIGNMENT	-	.75 FT
ANGULAR MISALIGNMENT	-	$\leq$5.0 DEG ROLL $\leq$6.0 DEG PITCH/YAW

- THE DOCKING MECHANISM WILL BE CAPABLE OF PERFORMING ACTIVE OR PASSIVE DOCKING/BERTHING.

SUMMARY

- DOCKING MODULE IS DESIGNED FOR EASY CHANGEOUT
- DOCKING MECHANISM IS DESIGNED FOR UNIVERSAL USAGE
- ADEQUATE AREA IS AVAILABLE FOR UTILITIES INTERFACES WITH GOOD ACCESS FOR MAINTENANCE/INSPECTION
- DOCKING MODULE DESIGN DOES NOT PRECLUDE THE INSTALLATION OF AIRLOCK CAPABILITY -- IF DESIREABLE
- STATUS OF MCR AND 25 KW POWER SYSTEM PROGRAMS DEMANDS EARLY DEFINITION OF REQUIREMENTS AND STANDARDIZATION
- WITH DOCKING MODULE AND HOLDING AND POSITIONING AID, THE ORBITER CAN DO ALL FORSEEABLE BERTHING/DOCKING AND SOC BUILD-UP OPERATIONS

BRIEFING OUTLINE

EXECUTIVE SUMMARY

ORBIT ALTITUDE STRATEGY

BERTHING & DOCKING

- DESIGN
- OPERATIONS

SOC BUILDUP & ASSEMBLY CONCEPTS

CONCLUSIONS & PLANS

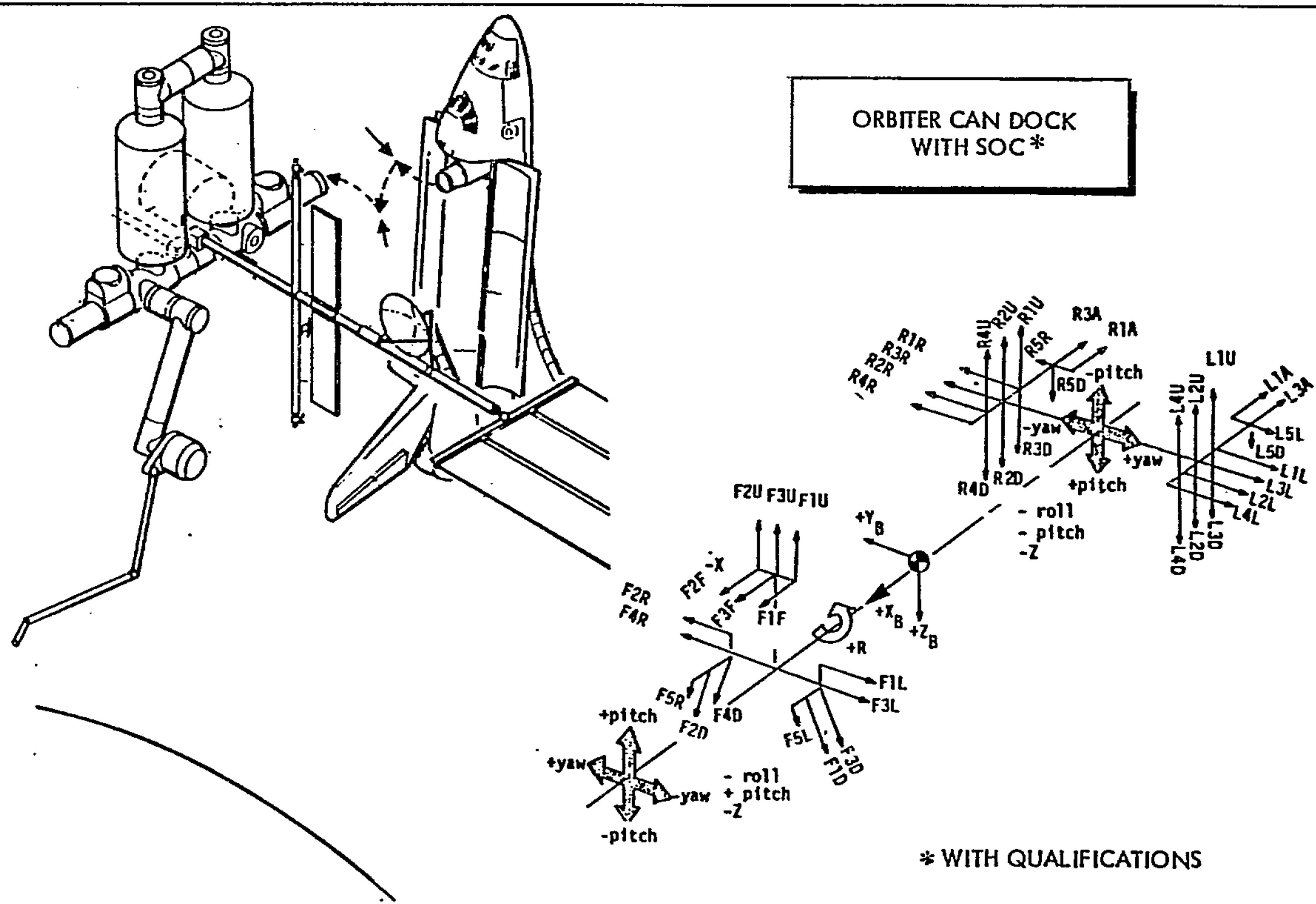
ORBITER DOCKING TRAJECTORY CONTROL

One of the main considerations in the berthing and docking task is the ability of the orbiter to safely perform the terminal closure trajectory leading to direct docking or RMS aided berthing of the orbiter to SOC. There are a number of complicating factors which can affect the degree of precision attainable for these proximity operations. The most notable of these are: the complex RCS thruster geometry on the orbiter which produces highly coupled motions, the relatively large minimum impulse bit size (65 ± 8 lb sec.) governed mainly by the orbiter digital auto-pilot sampling rate (12 H_z) and the coupling of these factors with orbit mechanics effects to degrade the precision of trajectory control.

However, in spite of these complexities, preliminary analyses with simplified models have indicated that the orbiter can dock with the Space Operations Center. The closing process is sufficiently slow that needed corrective impulses can be introduced to meet the docking contact conditions under normal operations. There are potential safety problems associated with non-normal situations such as a jet failure which require further attention.

ORBITER DOCKING TRAJECTORY CONTROL

ORBITER CAN DOCK
WITH SOC*



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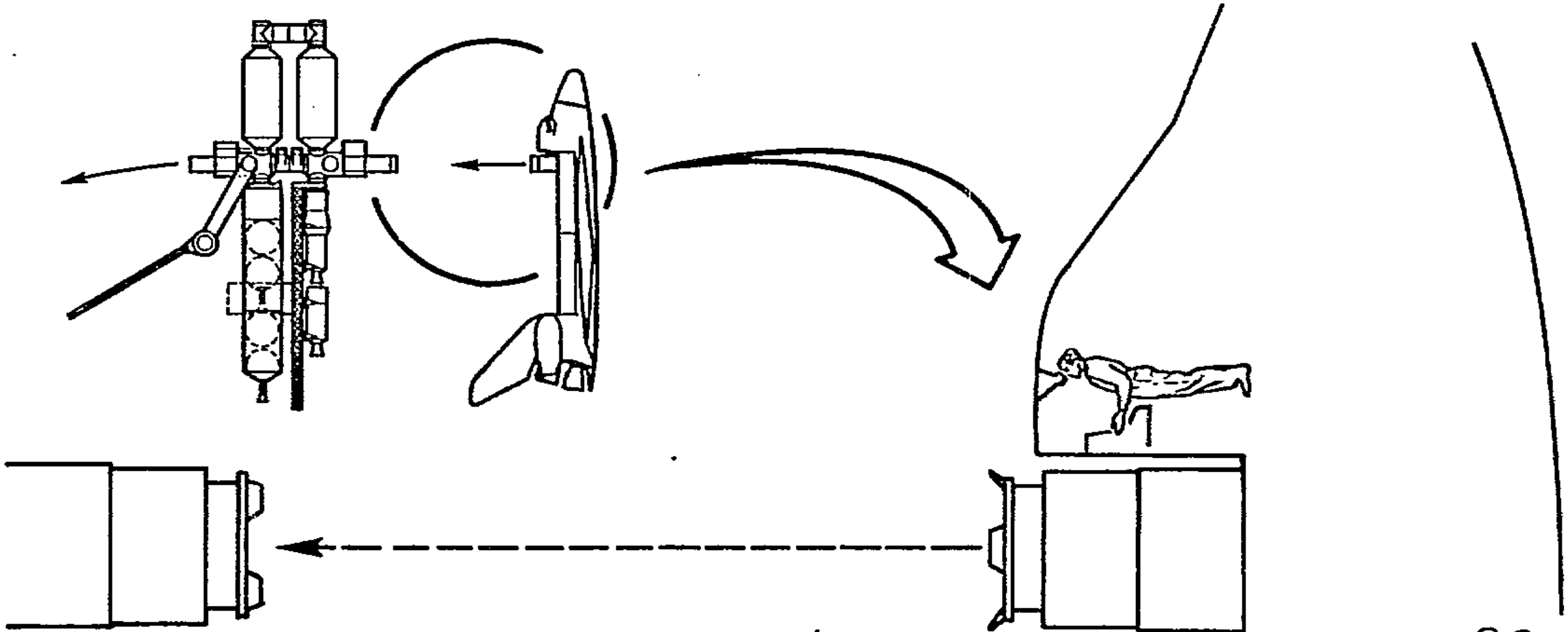
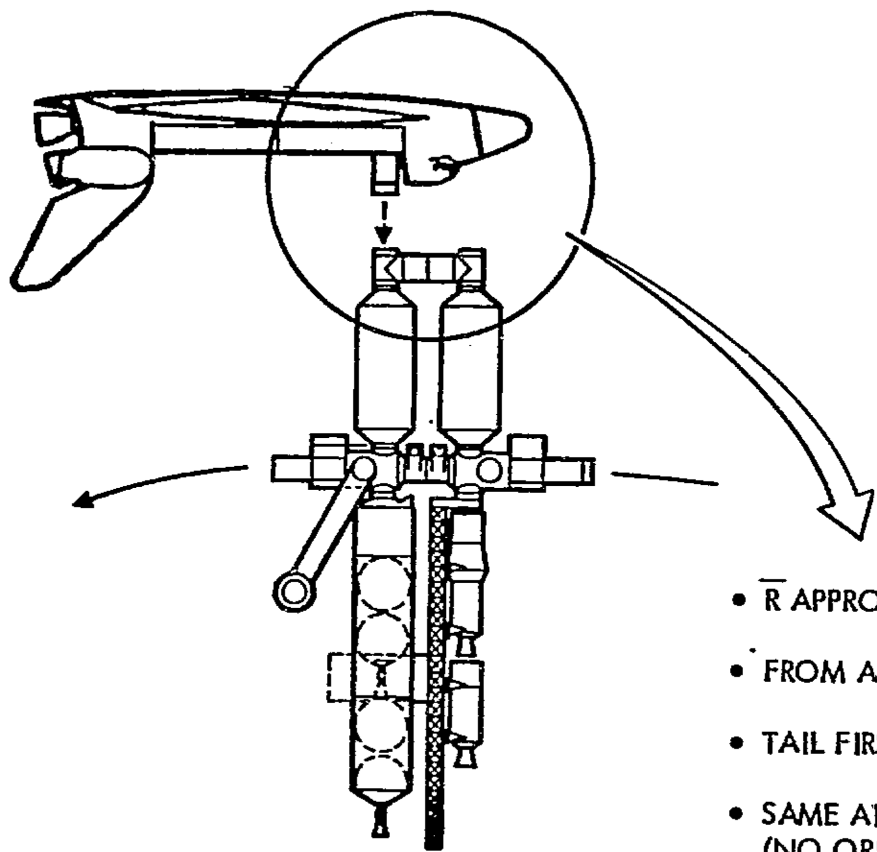
* WITH QUALIFICATIONS

ORBITER/SOC NOMINAL DOCKING SCENARIO



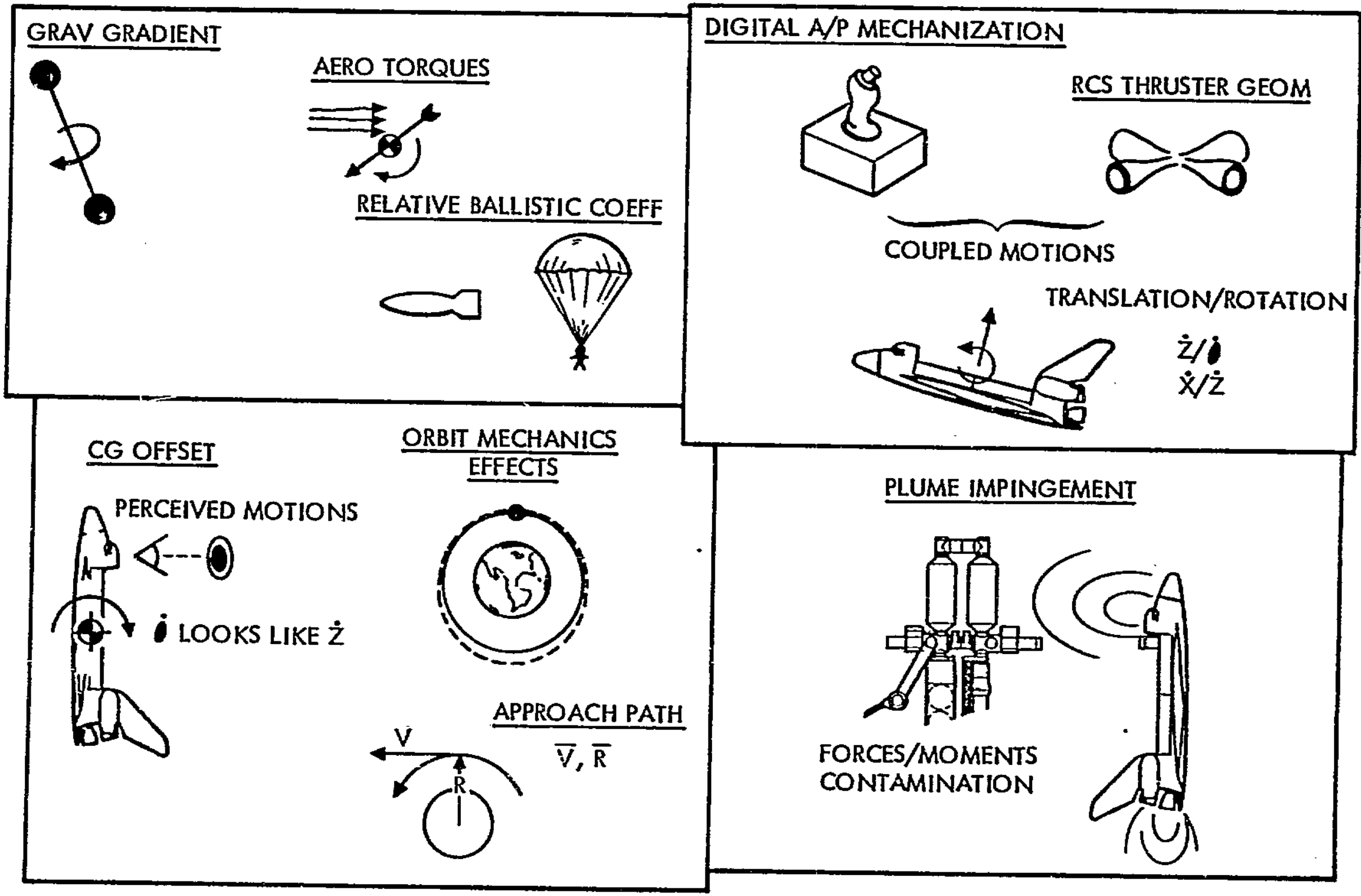
- $\overline{V}$ APPROACH
- TRAILING POSITION
- TAIL DOWN
- USE COAS + VIDEO DISPLAYS
- PRIMARY RCS
- LVH ROTATIONAL MODE
- ACCELERATION & PULSE TRANSLATIONAL MODES

ALTERNATE /EMERGENCY DOCKING SCENARIO

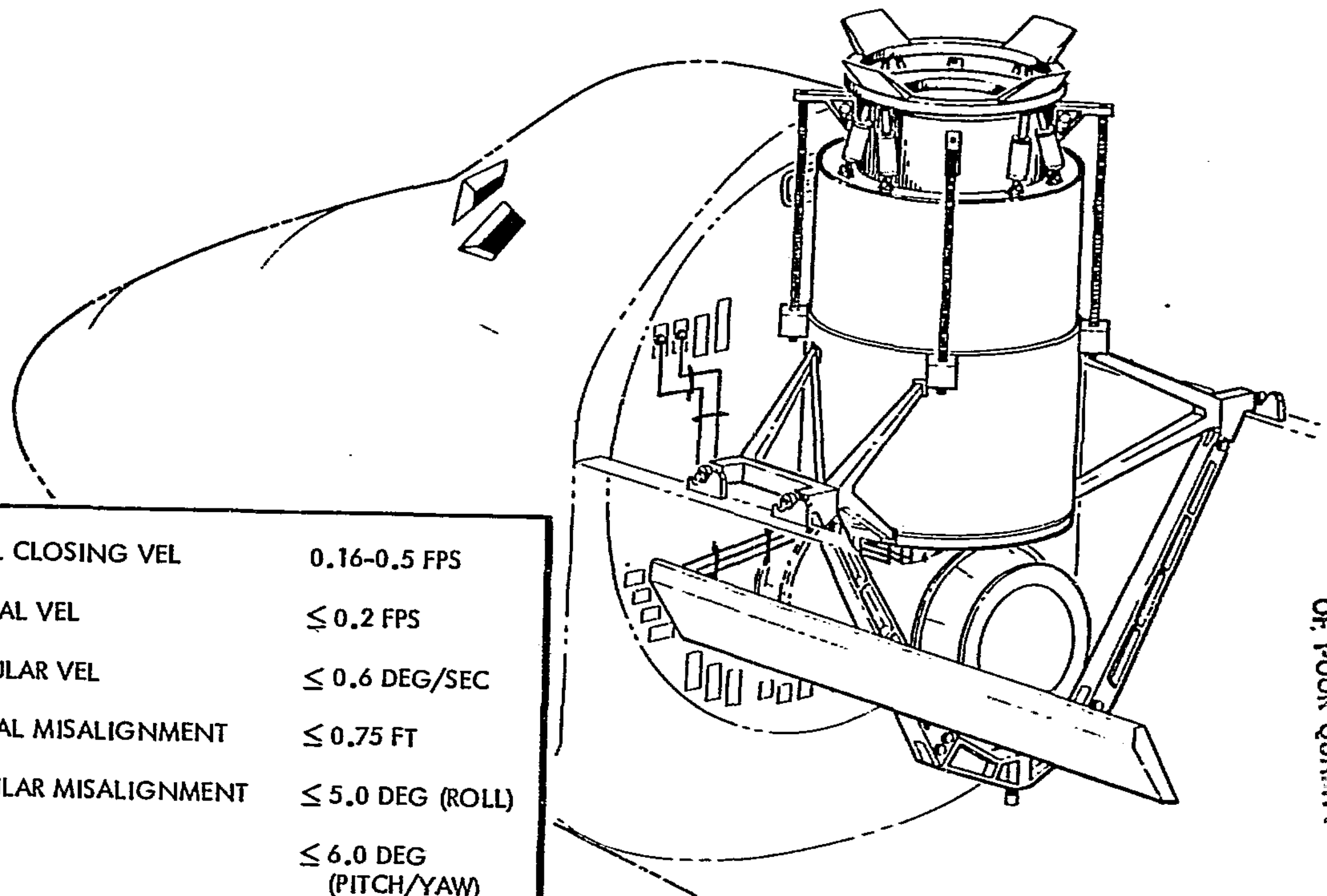


- $\overline{R}$ APPROACH
- FROM ABOVE
- TAIL FIRST & MAYBE OTHER ATTITUDES
- SAME AIDS & CONTROL MODES AS NOMINAL (NO ORBITER MODS)
- $\overline{R}$ MODIFIES ORBIT MECHANICS EFFECTS
- ADDITIONAL CREW TRAINING REQD

PROXIMITY OPERATIONS FACTORS



PRELIMINARY DOCKING REQUIREMENTS



AXIAL CLOSING VEL	0.16-0.5 FPS
LATERAL VEL	≤ 0.2 FPS
ANGULAR VEL	≤ 0.6 DEG/SEC
LATERAL MISALIGNMENT	≤ 0.75 FT
ANGULAR MISALIGNMENT	≤ 5.0 DEG (ROLL)
	≤ 6.0 DEG (PITCH/YAW)

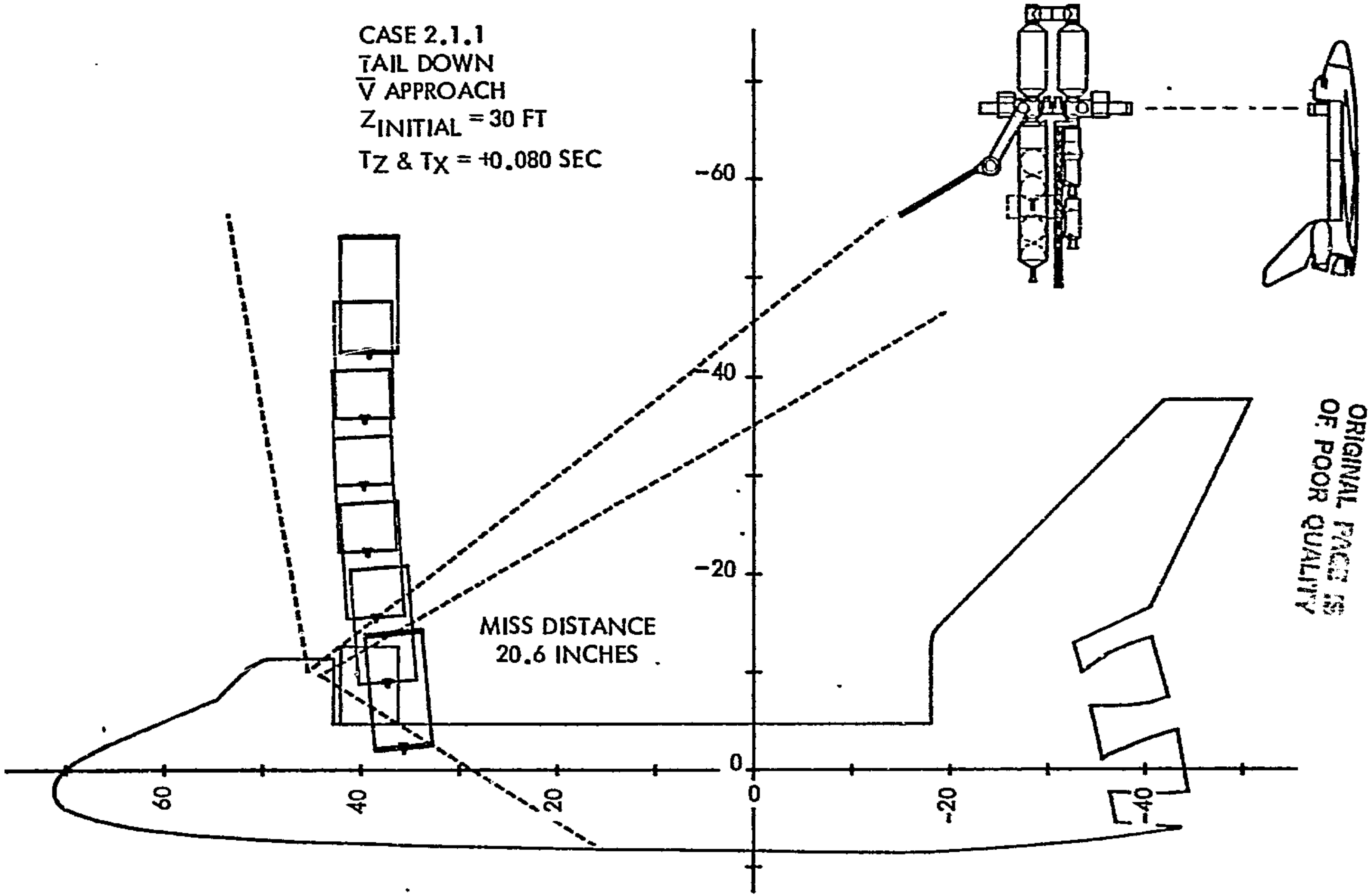
EXAMPLE DOCKING TRAJECTORY

This is an example printout from a series of closing trajectory runs made on a simplified relative motion simulation program. This simulation program includes the orbit mechanics effects on relative motion trajectories, the effects of the gravity/aero torque environments and the orbiter digital autopilot/thruster geometry characteristics affecting the precision of trajectory control. This simulation does not contain man-in-the-loop features, but does allow meaningful analyses of closing path sensitivities to approach direction (V-bar, R-bar, etc.), orbiter attitude, and the effects of ΔV errors caused by minimum impulse bit size limits. The case shown here was for plus ΔV errors in both X and Z directions (80 millisecond longer RCS burns than required for the ideal closure maneuver). The miss distance for this case is shown to be 20.6 inches.

A number of other cases were analyzed with different combinations of plus and minus ΔV errors and covering different closing geometries. The results of some of these additional simulation runs are summarized in the chart on the following page.

The main conclusion from this analysis is that the orbiter can be flown to successful docking contact conditions, but that "close in" ΔV adjustments, mostly in X and Y direction will be required. Also, the character and number of these corrective impulses will be affected by the closing geometry such as V-bar, R-bar, etc. and the orbiter attitude, tail up or down...or X-POP, etc.

EXAMPLE DOCKING TRAJECTORY



EXAMPLE DOCKING RESULTS

BASIC CONDITIONS: 30 FT, PLUS $\bar{V}$, TAIL DOWN, 1.8 MINUTE APPROACH PATH
IDEAL ΔV's ARE $\Delta V_{\bar{V}} = 0.2098$ FPS, $\Delta V_{\bar{R}} = 0.0258$ FPS

CASE	FIRING TIME (SEC) $-X_b$	FIRING TIME (SEC) $-Z_b$	FUEL USED (LB)	DOCKING PARAMETERS WRT SOC BODY AXES CENTERED ON DOCK PORT: DOCK TIME (SEC)	V_x (FT/SEC)	$\sqrt{V_x^2+V_y^2}$ (FT/SEC)	$\sqrt{\dot{\theta}_y^2+\dot{\theta}_x^2+\dot{\theta}_z^2}$ (DEG/SEC)	$\sqrt{X^2+Y^2}$ (IN.)	$\lvert\theta_x\rvert$ (DEG)	$\lvert\theta_y\rvert$ (DEG)	$\lvert\theta_z\rvert$ (DEG)
2.1.1	$T_I + .08$	$T_I + .08$	14.0	90.5	.329	.020	.030	20.6	.31	2.66	.01
2.1.2	$T_I + .08$	$T_I + .08$	14.7	95.7	.289	.030	.030	12.7	.34	.72	.00
2.1.3	$T_I + .08$	$T_I + .08$	13.0	111.0	.274	.003	.058	7.0	.46	7.07	.01
2.2.1	$T_I - .08$	$T_I + .08$	13.0	88.6	.331	.059	.045	14.3	.30	3.68	.01
2.2.2	$T_I - .08$	$T_I + .08$	13.7	92.4	.300	.070	.017	23.1	.33	2.20	.01
2.2.3	$T_I - .08$	$T_I + .08$	12.0	105.5	.285	.044	.044	48.4	.43	4.73	.02
2.3.1	$T_I - .08$	$T_I - .08$	10.0	109.7	.268	.037	.051	10.7	.24	5.55	.02
2.3.2	$T_I - .08$	$T_I - .08$	10.7	119.0	.230	.046	.010	4.8	.20	2.51	.01
2.3.3	$T_I - .08$	$T_I - .08$	9.0	138.4	.217	.004	.036	31.0	.41	5.25	.02
2.4.1	$T_I + .08$	$T_I - .08$	11.0	113.6	.268	.004	.037	54.6	.27	4.38	.01
2.4.2	$T_I + .08$	$T_I - .08$	11.7	119.0	.228	.056	.010	19.4	.23	2.50	.01
2.4.3	$T_I + .08$	$T_I - .08$	10.0	147.1	.207	.016	.050	25.7	.44	7.66	.01
2.5.1	$T_I + .08$	$T_I + .08$	13.7	91.6	.326	.029	.028	10.2	.24	2.49	.01
2.5.2	$T_I + .08$	$T_I + .08$	14.5	96.5	.287	.039	.039	1.8	.28	.50	.01
2.5.3	$T_I + .08$	$T_I + .08$	12.7	111.4	.273	.011	.060	19.3	.38	6.78	.01
2.6.1	$T_I - .08$	$T_I + .08$	13.2	91.0	.327	.049	.535	7.7	.24	3.19	.01
2.6.2	$T_I - .08$	$T_I + .08$	14.0	94.8	.291	.039	.025	16.5	.26	1.24	.01
2.6.3	$T_I - .08$	$T_I + .08$	7.0	108.3	.280	.032	.053	40.4	.32	5.82	.01
2.7.1	$T_I - .08$	$T_I - .08$	10.3	112.5	.266	.028	.043	19.8	.19	4.79	.01
2.7.2	$T_I - .08$	$T_I - .08$	11.0	121.5	.226	.036	.017	4.9	.23	1.55	.00
2.7.3	$T_I - .08$	$T_I - .08$	9.3	142.3	.213	.014	.044	19.2	.35	6.46	.01
2.8.1	$T_I + .08$	$T_I - .08$	10.8	114.3	.266	.008	.036	42.1	.19	3.98	.01
2.8.2	$T_I + .08$	$T_I - .08$	11.5	124.2	.223	.016	.024	28.6	.25	.61	.00
2.8.3	$T_I + .08$	$T_I - .08$	10.8	147.0	.207	.007	.051	9.6	.35	7.72	.01

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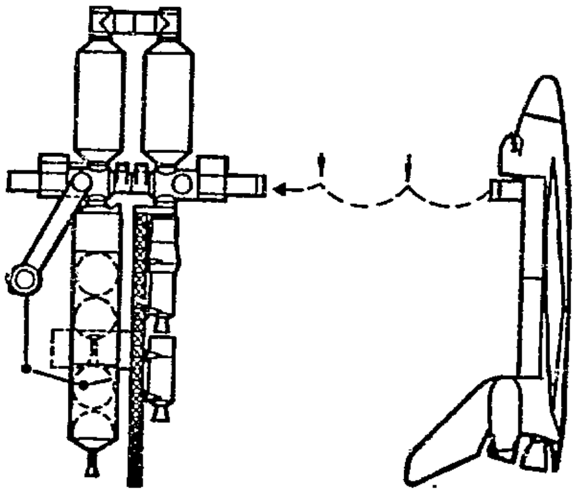
Space Operations and Satellite Systems Division

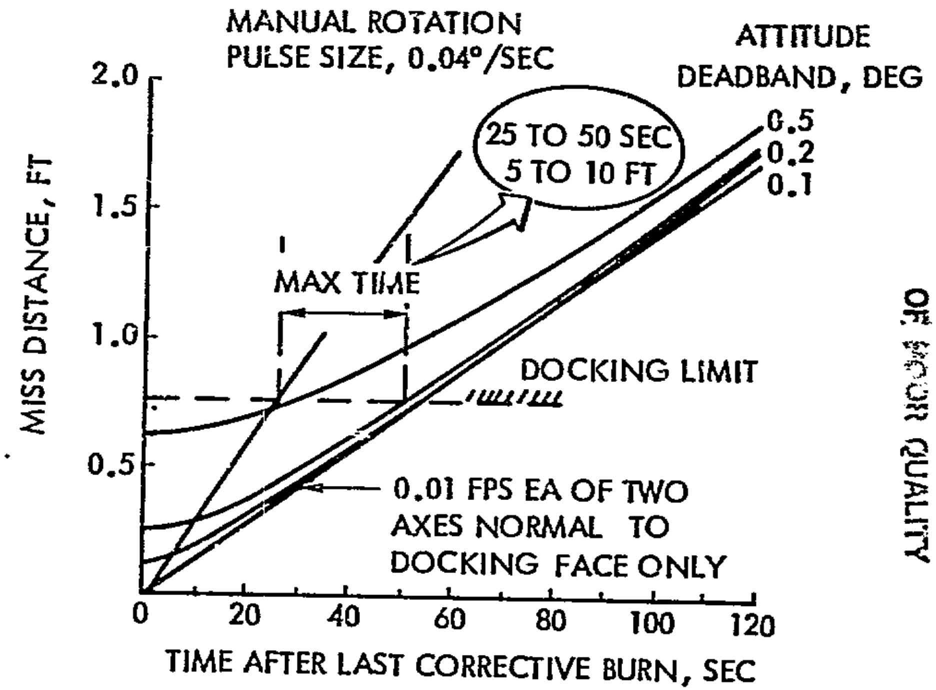
Rockwell International

DOCKING TRAJECTORY ACCURACY

"ORBITER CAN DO THE JOB"

- PROXIMITY RCS FIRING REQUIRED
- MOSTLY X_B & Y_B CORRECTIONS..... WITH SOME ROTATIONAL HOLD ATTITUDE FIRINGS





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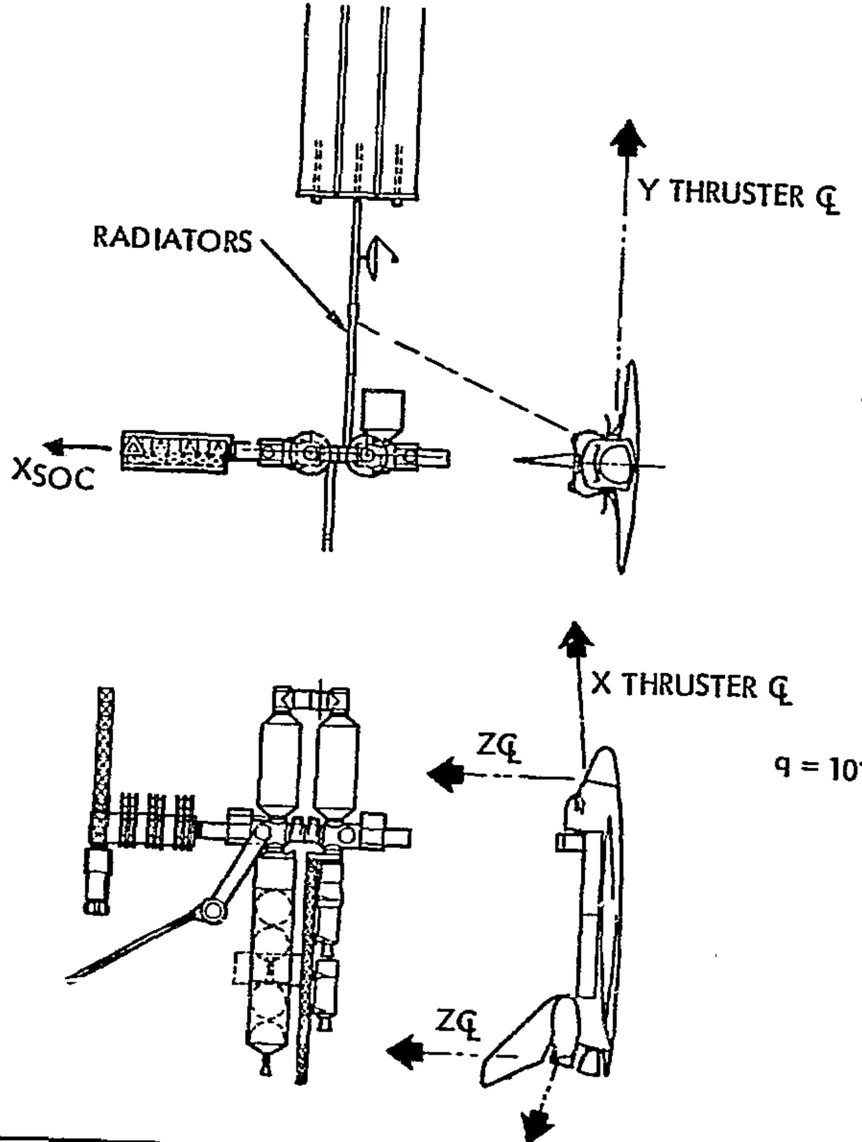
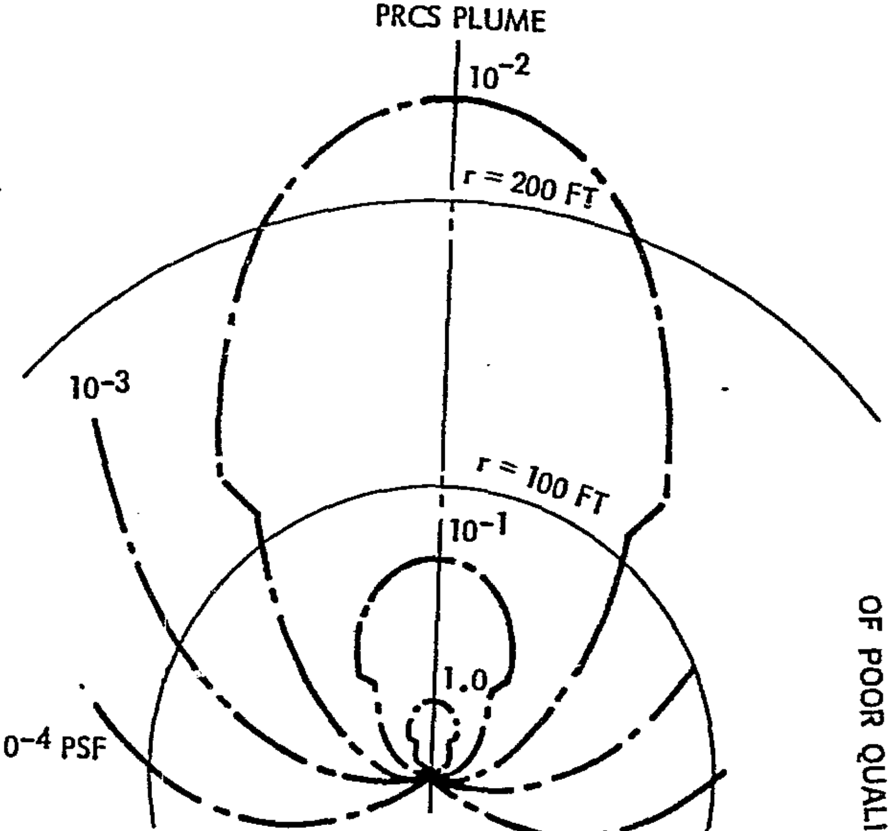
RCS PLUME IMPLICATIONS





- X & Y THRUSTING PRODUCE MINIMAL EFFECTS
- NEGLIGIBLE Z THRUSTING EXPECTED (NOMINAL APPROACHES)

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JSC TERMINAL CLOSURE SIMULATION RESULTS

The only terminal closure simulations involving man-in-the-loop with high fidelity orbiter flight control characteristics were conducted by JSC in support of LDEF retrieval investigations. The objectives of this simulation activity are summarized on the accompanying chart along with some of the conclusions judged to be pertinent to the current SOC study. The results identified problem sensitivities to approach path and orbiter attitudes similar to those described from recent studies in the preceding charts. However, piloting techniques were developed which indicated the capability to fly up to and stationkeep with a co-orbiting target vehicle to within 0.03 fps relative velocity in all axes. This is well within the docking contact velocity envelope specified for SOC and thus confirms the belief that the orbiter can successfully dock with the Space Operations Center under normal conditions.

JSC TERMINAL CLOSURE SIMULATION RESULTS

STUDY APPROACH PATH OPTIONS TO LDEF, JSC - 12776, NOV 7, 1977

OBJECTIVES:

- ORBITER CAPABILITY TO APPROACH & STATIONKEEP WITH PLUME SENSITIVE P/L
- ESTABLISH PERFORMANCE DATA BASE FOR VARIOUS APPROACH TECHNIQUES

RESULTS:

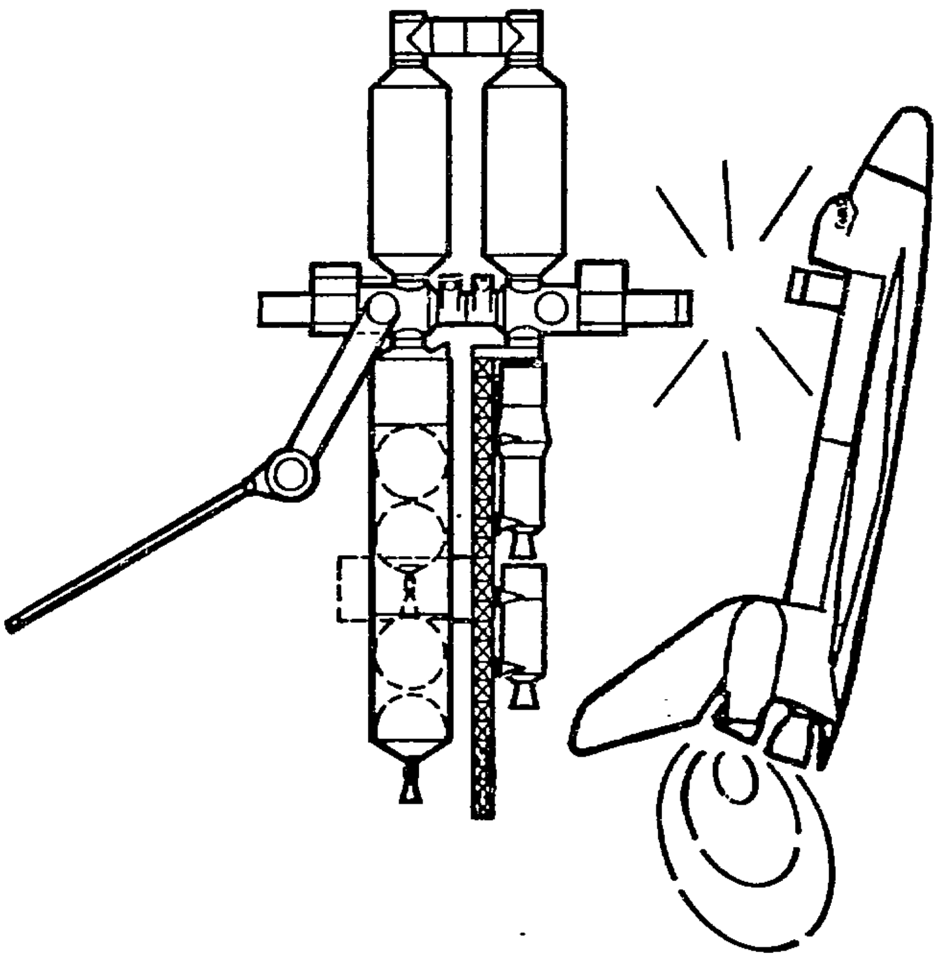
- $\bar{R}$ & $\bar{V}$ APPROACHES OFFER OPERATIONAL ADVANTAGES
- $\bar{H}$ APPROACHES ARE CONDITIONALLY FEASIBLE
- <u>ALL</u> APPROACH MODES SHOULD BE CONSIDERED
- PILOTS CONSISTANTLY MAINTAINED STATIONKEEPING WITHIN 0.03 FPS ALL AXES
- SPECIAL TECHNIQUES CAN GREATLY REDUCE PLUME EFFECTS ±X PRCS ("LOW Z") BRAKING
- FORE & AFT CCTV's ARE VALUABLE AIDS FOR FINAL CLOSURE

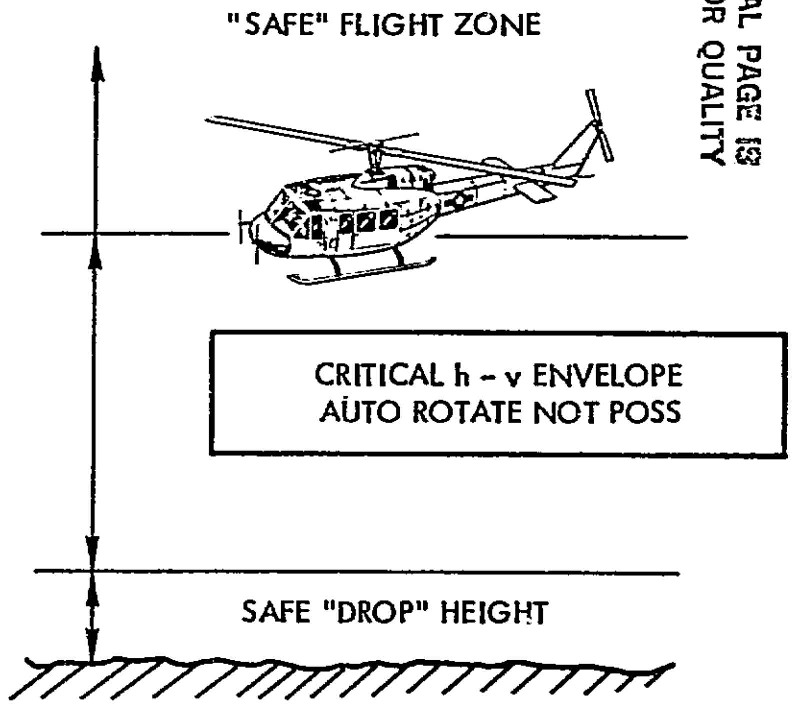
A TOTAL OF 20 CONCLUSIONS & RECOMMENDATIONS ON TECHNIQUES, TRENDS, & SENSITIVITIES RELATIVE TO PLUME EFFECTS & FUEL CONSUMPTION

THE PROBLEM IS A RUNAWAY JET FAILURE

POTENTIAL CRITICAL REGION
- MISS DOCKING ENVELOPE
- RECOVERY DIFFICULT
- ORBITER - SOC CONTACT LIKELY

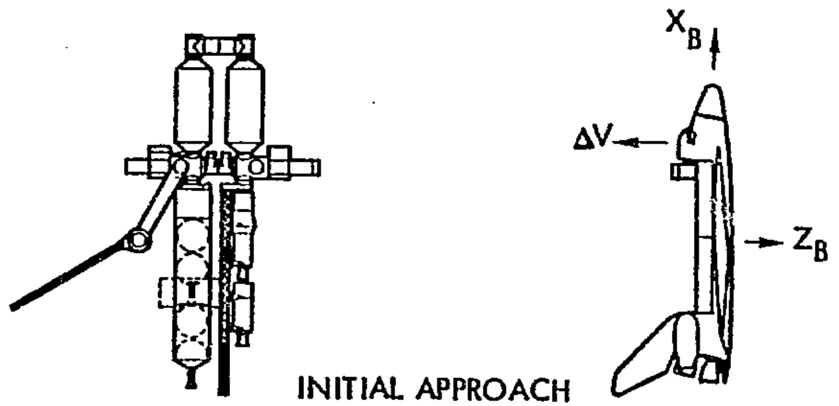
ANALOGOUS TO HELICOPTER CRITICAL FLIGHT ZONE





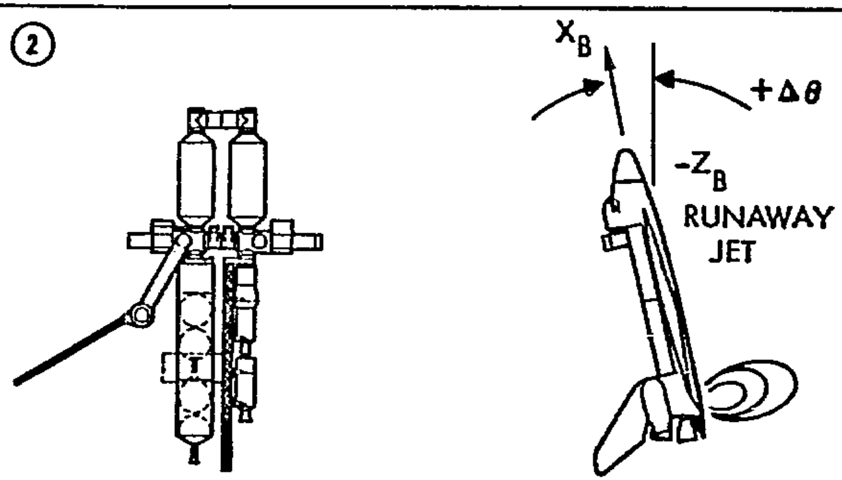
DOCKING ABORT SCENARIO

1



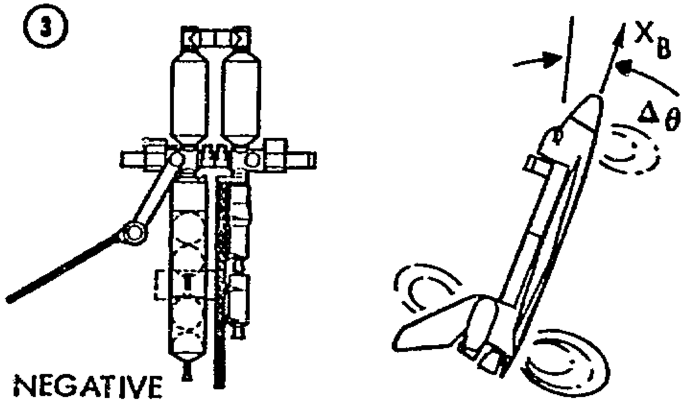
INITIAL APPROACH
TAIL DOWN
$\Delta V = 0.5$ FPS

2



RUNAWAY JET OCCURS AT
+0.5 DEG DEADBAND

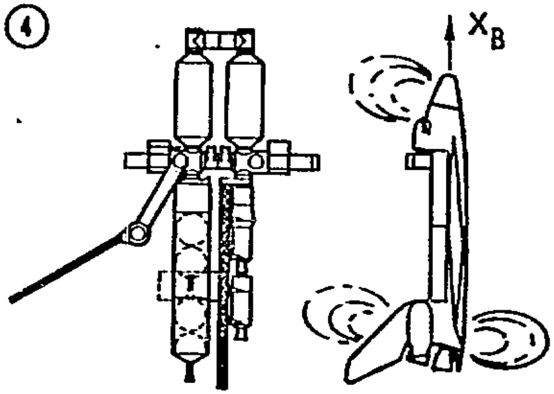
3



NEGATIVE
DEADBAND ENCOUNTED....
RECOVERY STARTED
- 2 JET COUPLE, STOP $\dot{\theta}$
- 3 JET ACTION, $\dot{Z}$ ABORT (NET 2 JETS)

$\Delta d = 26.1$ INCHES
$\Delta \theta =$ AT -0.5 DEG
$\Delta \dot{\theta} = 0.65$ DEG/SEC

4



CLOSING MOTION ARRESTED....
TOTAL DISTANCE, $\Delta d \approx 44.5$ INCHES
MAX ANGLE EXCURSION, $\Delta\theta \approx -0.9$ DEG

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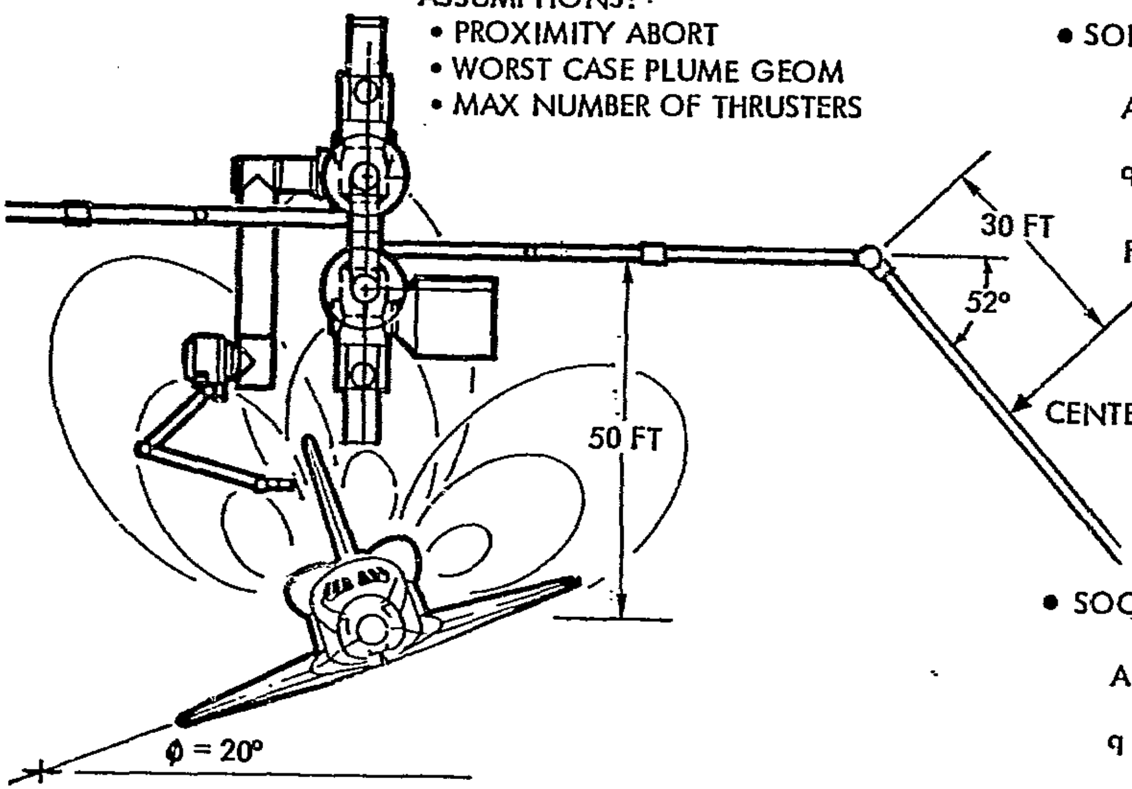
"WORST CASE" PLUME EFFECTS

ASSUMPTIONS:
- PROXIMITY ABORT
- WORST CASE PLUME GEOM
- MAX NUMBER OF THRUSTERS



PLUME INDUCED FORCES & MOMENTS
$\Sigma F_{PLUME} = 2408$ LB
$\Sigma M_{PLUME} = 22490$ FT LB

- SOLAR ARRAY

  $A = 28 \times 127 \times \sin 72° \approx 3400\ FT^2$

  $q = 3 \times 10^{-2} \times 2$ THRUSTERS $\approx 6 \times 10^{-2}$ PSF

  $F = 2 \times 6 \times 10^{-2} \times 3400 = 408$ LB

- SOC BODY

  $A = 40 \times 14 + \frac{14^2}{4} \approx 720\ FT^2$

  $q = 2.5 \times 10^{-1} \times 4$ THRUSTERS ≈ 1 PSF

  $F = 2 \times 1.0 \times 720 \approx 1440$ LB

- RADIATORS

  $A = 4 \times 7.5 \times 23.3 \approx 700\ FT^2$

  $q = 10^{-1} \times 4$ THRUSTERS $\approx 4 \times 10^{-1}$ PSF

  $F = 2 \times 4 \times 10^{-1} \times 700 \approx 560$ LB

OPTIONS FOR DOCKING SAFETY

- DETERMINE IF SPECIAL PROCEDURES CAN SATISFY SAFETY REQ
- IMPROVE SOFTWARE TO REDUCE RUNAWAY JET RESPONSE TIME
- MODIFY VRCS . . . . ADD THRUSTERS TO PROVIDE TRANSLATION CAPABILITY FOR "CLOSE-IN" MANEUVERS
- MODIFY SOC - ORBITER DOCKING PROVISIONS . . . .
  - EXPAND CONTACT ENVELOPE
  - "ARMOR" TO PROTECT POTENTIAL CONTACT AREAS
- INVESTIGATE THE USE OF RMS/BERTHING INSTEAD OF DIRECT DOCKING . . . . REQUIRES LOOK AT
  - RMS SINGLE POINT FAILURE POTENTIAL & RELATED HAZARDS
  - RUNAWAY JET IMPLICATIONS

REQUIRES MAN-IN-THE-LOOP SIMULATIONS TO VERIFY THE NEED &/OR SOLUTIONS TO DOCKING SAFETY

MAJOR SIMULATION FACILITIES

FACILITY	CAPABILITY	AVAILABILITY	RESP ENGR
JSC	SES – SHUTTLE ENGINEERING SIM HI-FI SYST, REAL TIME RELATIVE MOTION, FLEX ARM RMS VISUAL AIDS	SOC PRIORITY RANK > 15	H. ROSENBERG
	SAIL – SHUTTLE AVION INTEG LAB SMS – SHUTTLE MISSION SIM	COMMITTED TO STS NO. 1	
ROCKWELL	FSL – FLIGHT SIM LAB HI-FI SYST, REAL TIME VISUAL AIDS – ENTRY, ASCENT RELATIVE MOTION CAPABILITY	COMMITTED TO STS NO. 1	J. DUNGAN
	PDRSS – P/L DEPLOY & RETRIEVAL SYST SIM NON-REAL TIME ORBITER/DAP MOTION, FLEX ARM RMS PROVISIONS FOR FLEX P/L	EST OPERATIONAL NOV 1980	D. BROCKSCHMIDT
SPAR	SIMFAC – SIMULATION FACILITY ORBITER/DAP PROVISIONS FLEX ARM RMS CRT VISUAL AIDS	CURRENTLY AVAIL	B. FULLER
	ENGR SIM NON-REAL TIME FLEX ARM RMS	CURRENTLY AVAIL	B. FULLER

PENDING SPAR/ROCKWELL INTERNATIONAL SIMULATIONS

CURRENTLY HOLDING DISCUSSIONS ON WAYS ROCKWELL INTERNATIONAL & SPAR CAN WORK TOGETHER TOWARD . . .

✓ CLARIFICATION OF RMS CAPABILITY FOR

  ORBITER/SOC BERTHING

✓ GROSS FEASIBILITY EVALUATIONS

  REMOVAL OF RESIDUAL RELATIVE MOTIONS

  POSITIONING OF ORBITER TO SOC BERTHING PORT

BERTHING AND DOCKING SUMMARY

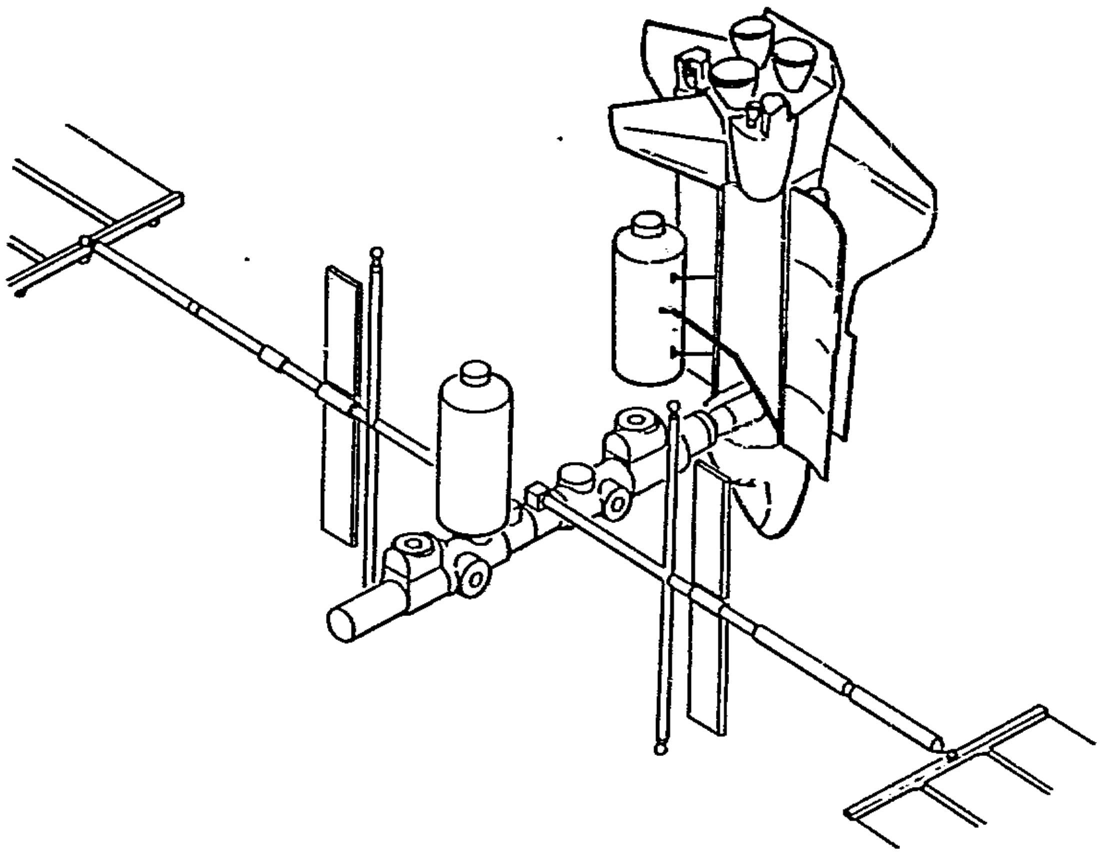
- A VERSATILE DOCKING MODULE CONCEPT HAS BEEN DEFINED
- BASIC REQUIREMENTS/CRITERIA ESTABLISHED FOR STS/SPACE PROG CONSIDERATION
- ORBITER CAN DOCK WITH SOC . . . . BUT SAFETY ISSUES REQUIRE ADDITIONAL EVALUATION
- POTENTIAL SAFETY ISSUE WITH RUNAWAY JET . . . . FURTHER EXCURSION ENVELOPE/CORRIDOR BEING DEVELOPED
- THERE ARE SOLUTIONS TO SAFETY ISSUES . . . . MAN-IN-THE-LOOP SIMULATIONS ARE NEEDED
- DESIRED "FULL UP" SIMULATION CAPABILITY CURRENTLY UNAVAILABLE FOR SOC . . . . LIMITED SIM ANALYSIS PENDING, ROCKWELL INTERNATIONAL/SPAR
- FURTHER DEFINITION OF PLUME EFFECTS PLANNED
- RECOMMEND KEEPING BOTH BERTHING & DOCKING OPTIONS FOR SOC

BRIEFING OUTLINE

- EXECUTIVE SUMMARY
- ORBIT ALTITUDE STRATEGY
- BERTHING & DOCKING
- SOC BUILDUP & ASSEMBLY CONCEPTS
- CONCLUSIONS & PLANS

SOC ASSEMBLY

SOC SHOULD BE – AND CAN BE – DESIGNED TO ACCOMMODATE BUILD-UP BY ANY OF SEVERAL SCENARIOS



POTENTIAL SOC SCENARIOS

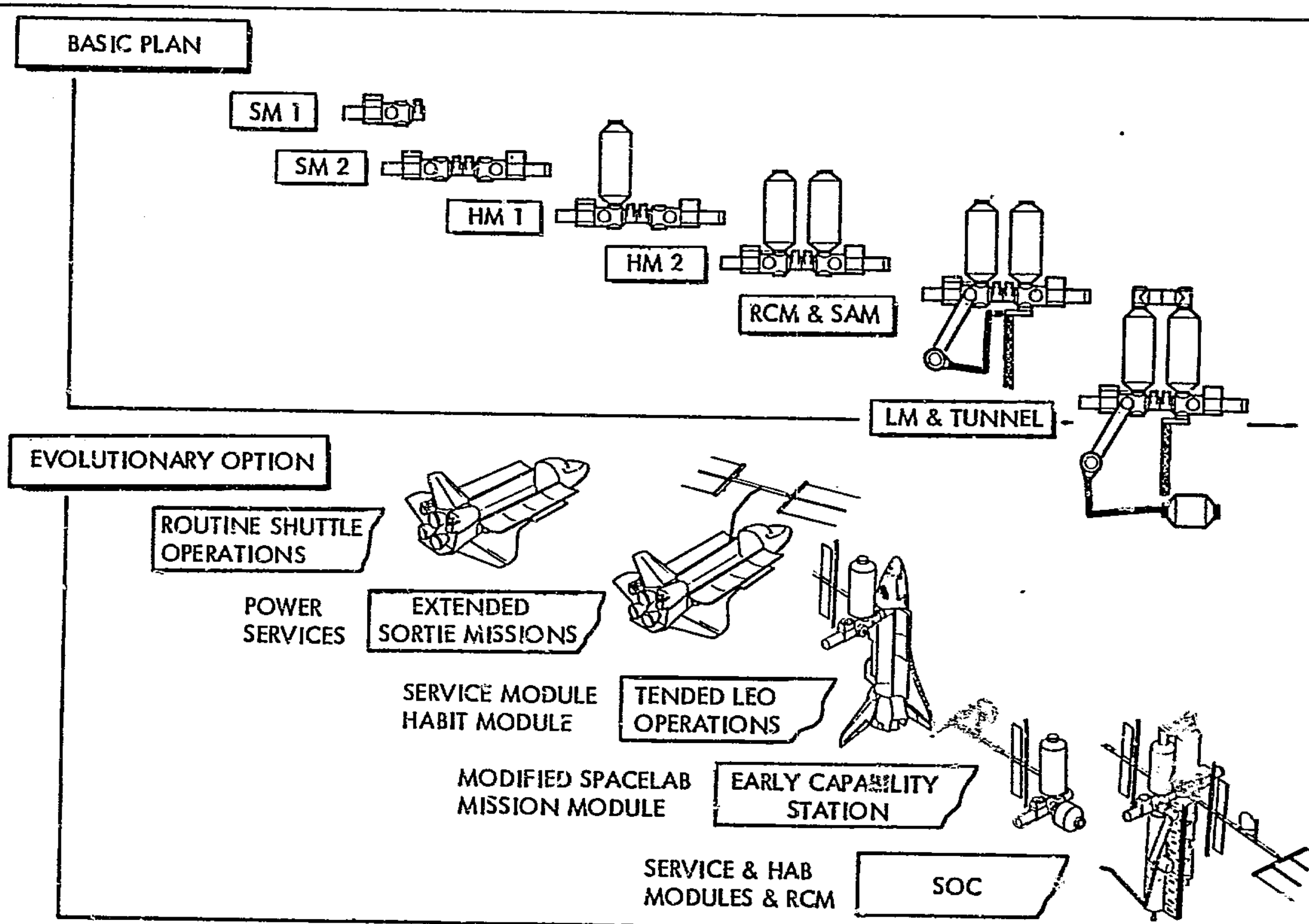
This chart illustrates two possible SOC buildup scenarios. The top scenario depicts the basic plan in which the various SOC modules are produced and delivered in the most logical sequence to achieve "full-up" operational capability in the earliest feasible time period.

This plan, which is in accord with NASA guidelines, has been examined in detail to determine the orbiter's capability to deliver and assemble the SOC system.

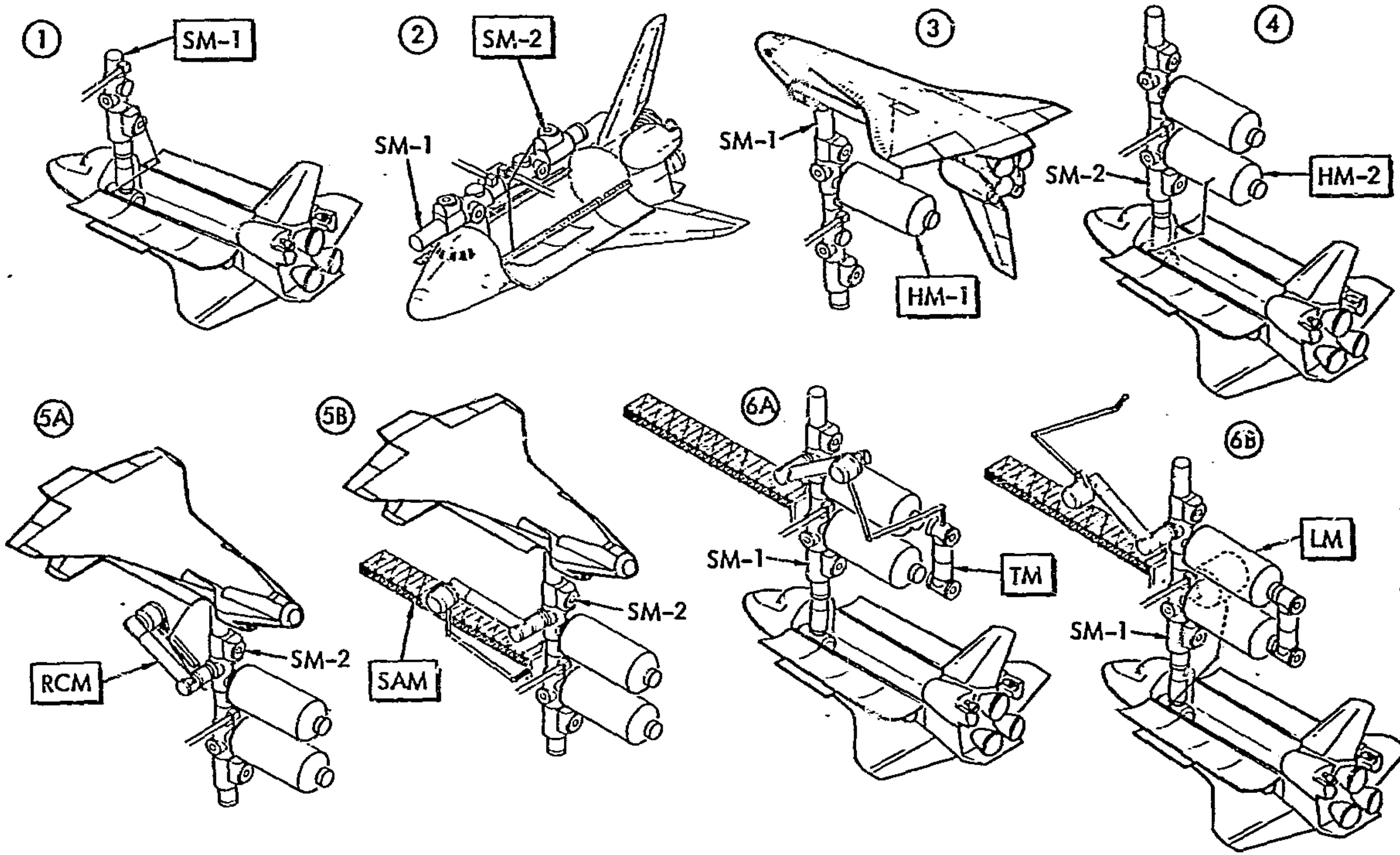
The second scenario shows one of many possible "evolutionary" build-up options. In this scenario, the orbiter's sortie capability would first be augmented by the power extension package (PEP). For longer more-advanced missions, the initial SOC service and habitability modules would be assembled to provide necessary services and comfortable crew quarters. Eventually, the economic drive to improve the utilization of the Shuttle fleet might lead to the earliest autonomous SOC. In the case shown, the spacelab might be accommodated as a mission module on the early SOC. However, for accommodation aboard SOC, the spacelab mission module would require extensive modifications in the areas of meteoroid protection, heat rejection, hatches, and structure. Other possible mission modules might include payload pallets.

With the delivery of the remaining modules, the SOC's full-up operational capability would be achieved.

POTENTIAL SOC SCENARIOS



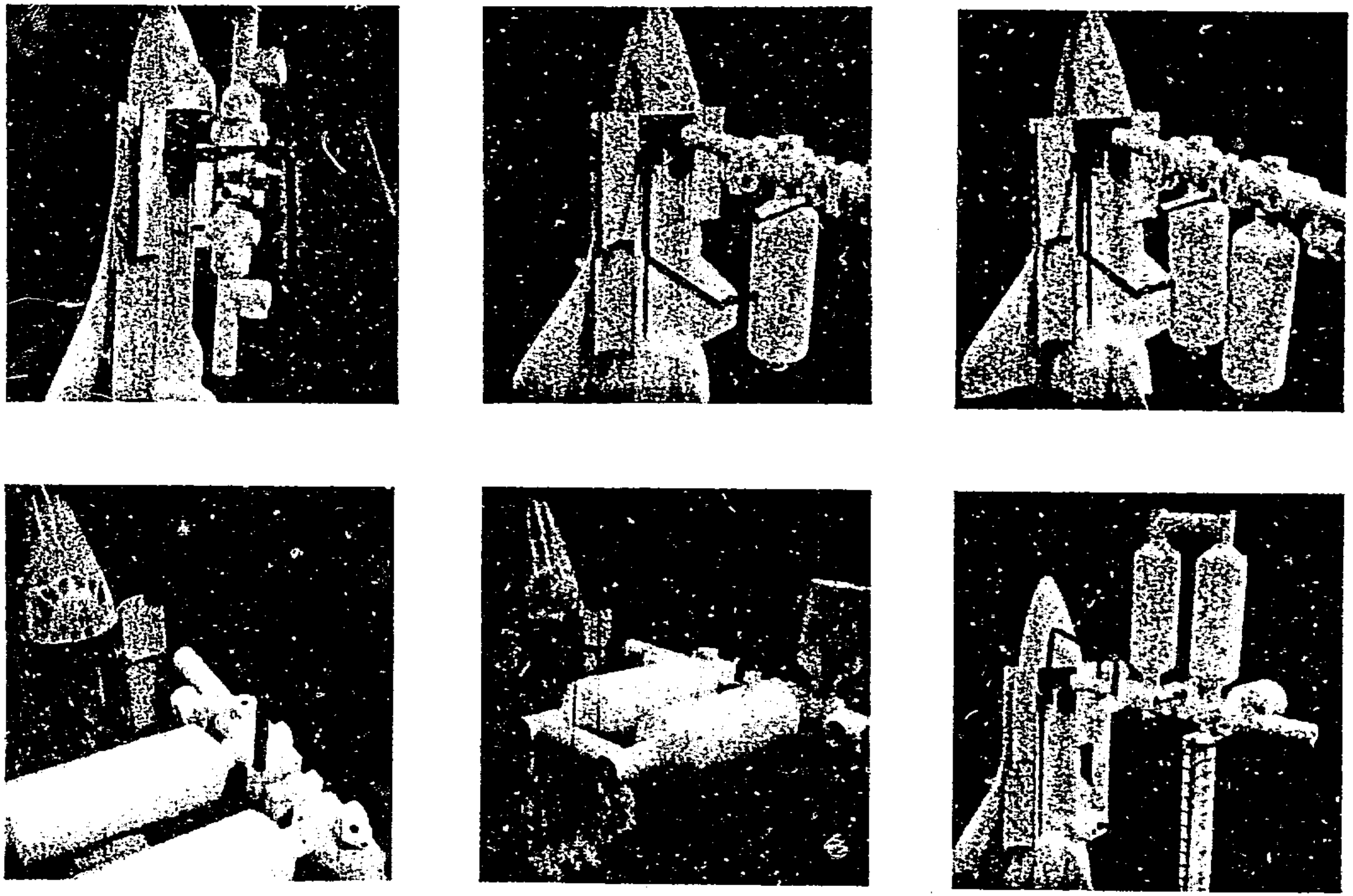
SOC ASSEMBLY SEQUENCE
BASELINE CONCEPT



BUILDUP EVALUATION TECHNIQUE

One of the tools we used to verify the results of our SOC buildup analysis is a scale model of the orbiter and the various SOC modules. The 1/48 scale model was of a sufficient fidelity to verify all docking/berthing orientations, reach distances and translation paths. The subject of this photographic sequence was a variation to the baseline buildup concept in which the SOC was berthed to a holding and positioning aid as shown in the bottom left photograph.

BUILDUP EVALUATION TECHNIQUE



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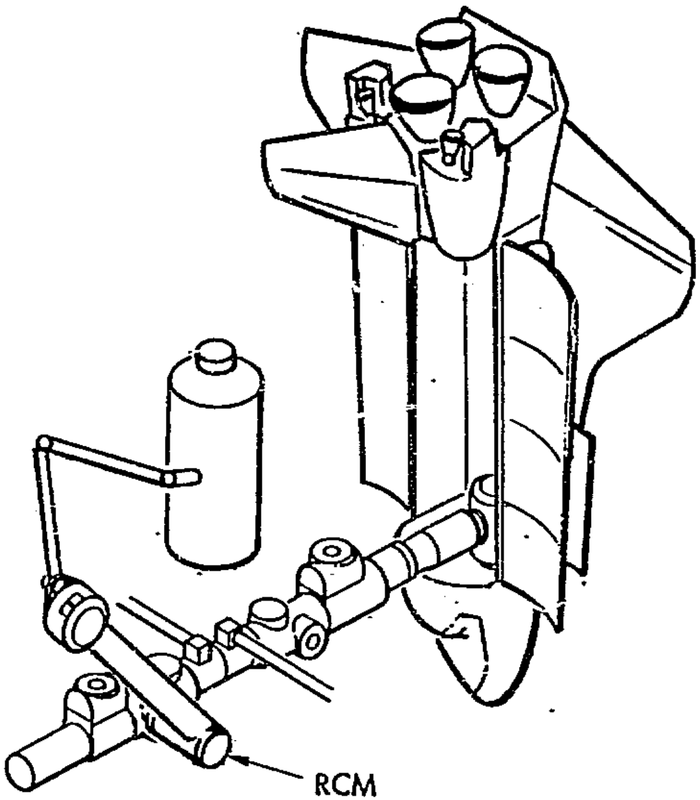
FEATURES

- THREE DOCKING PORTS USING STANDARD DOCKING INTERFACE
- USE RCM FOR TUNNEL INSTALLATION
- HABITABLE AFTER 6TH FLIGHT
- STANDARD ORBITER WITH DOCKING MODULE, PIDA, AND LIGHTS CAN PERFORM SOC ASSEMBLY

RCM ASSIST TO SOC ASSEMBLY

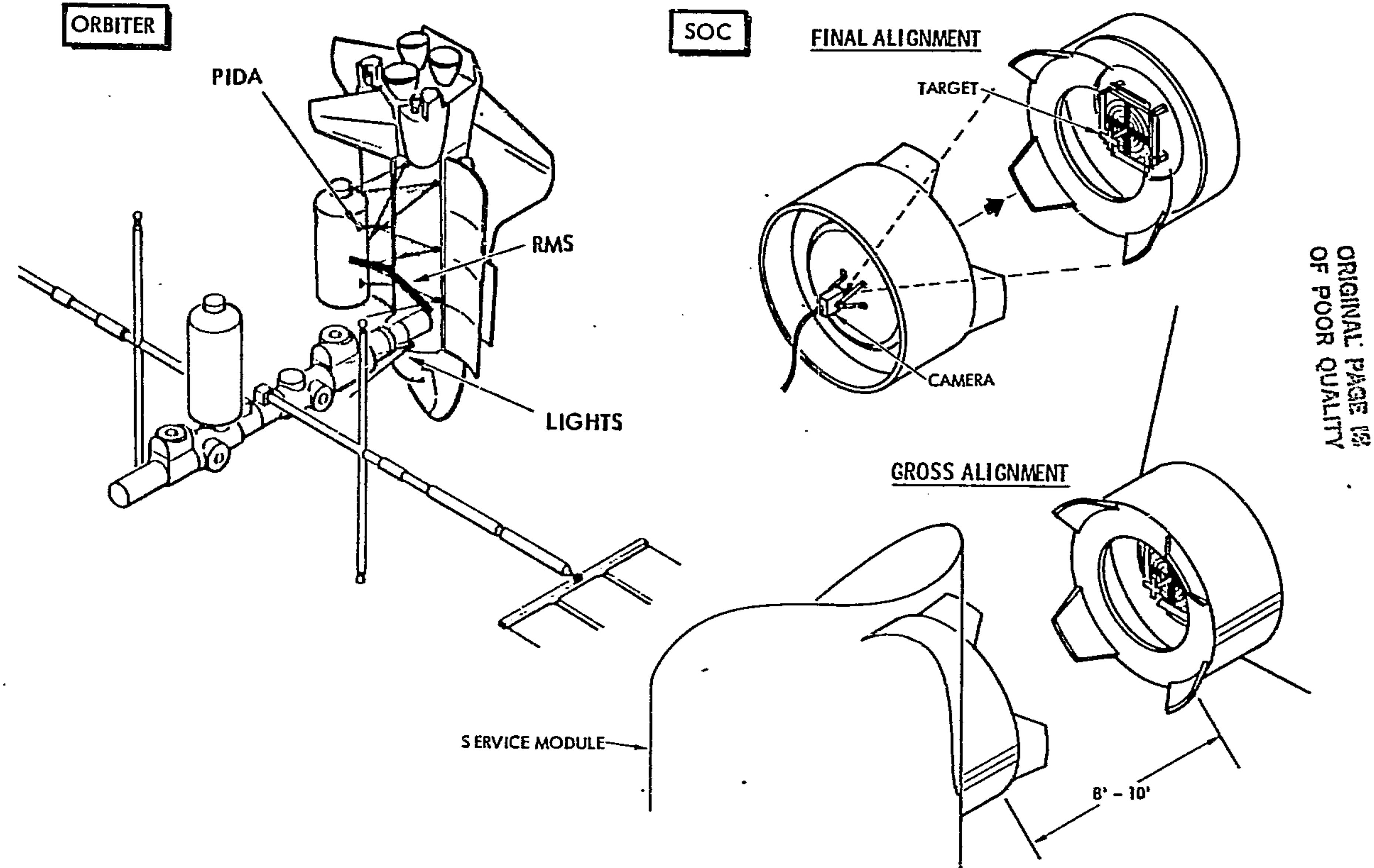
TIMING OF RCM INSTALLATION CAN BE SIGNIFICANT TO SOC BUILD-UP



IMPLICATIONS

- SIMPLIFIES MODULE ASSEMBLY MANEUVERS
- PROVIDES DIRECT VISIBILITY OF OPERATION
- REQUIRES MANNED ENTRY WITH SOC DURING MAJOR ASSEMBLY OPERATIONS

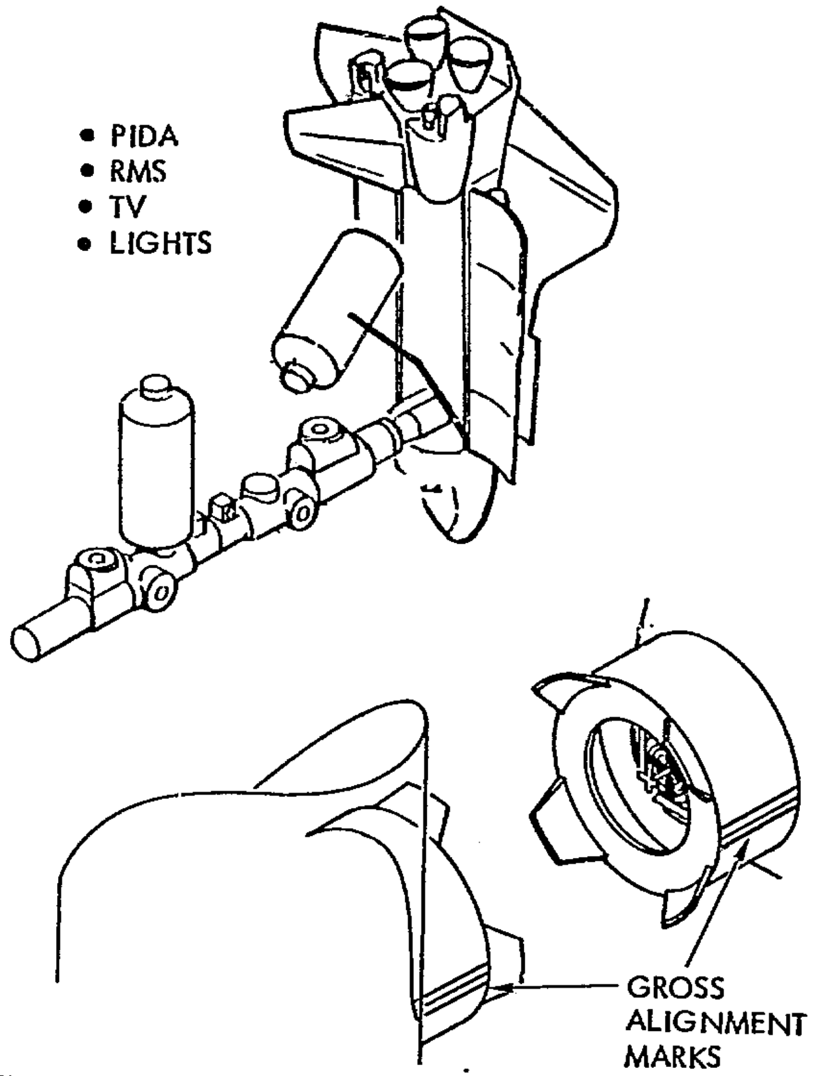
ASSEMBLY AIDS



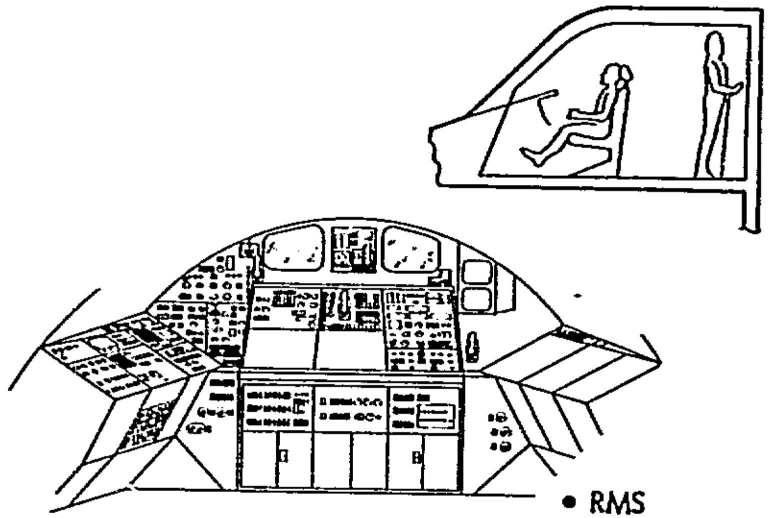
BERTHING ALIGNMENT AIDS

MODULE POSITIONING PHASE

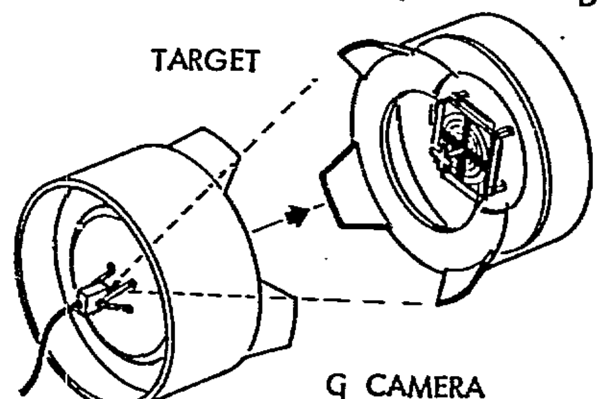
- PIDA
- RMS
- TV
- LIGHTS



FINAL BERTHING PHASE



- RMS
- ℄ TV AID
- VIDEO DISPLAYS

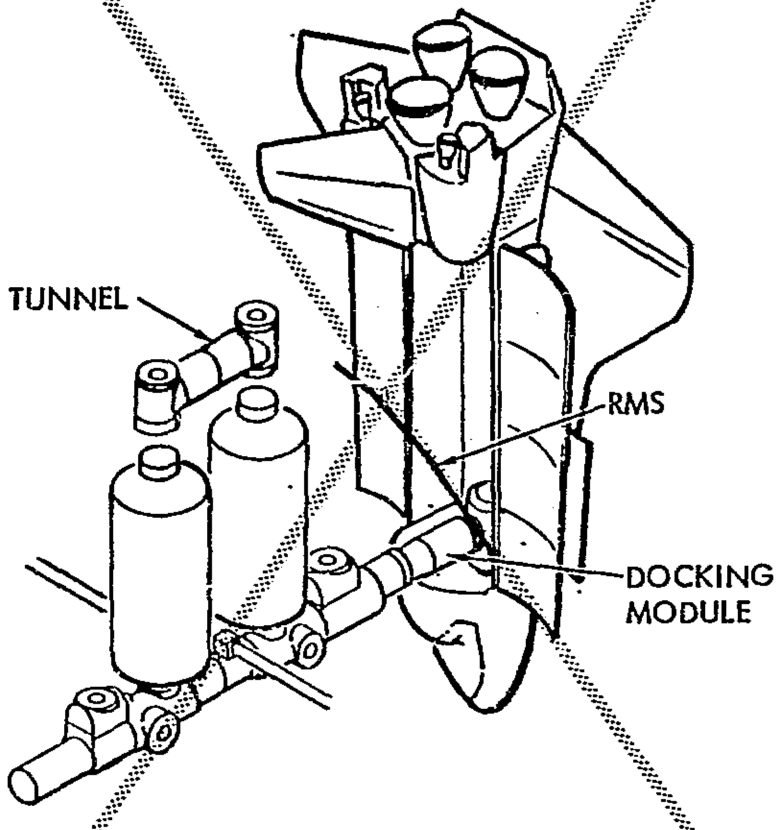


RMS TUNNEL INSTALLATION

Another variation to the baseline buildup sequence assumes that the RMS Control Module (RCM) is not available to attach the tunnel - a most difficult operation. If the SOC is docked with the Docking Module, the RMS reach is inadequate for attaching the Tunnel. However, if the SOC was berthed to a holding and positioning aid (HAPA) rather than the Docking Module, then the RMS reach becomes quite adequate for attaching the Tunnel. This capability was also verified by the 1/48 scale model.

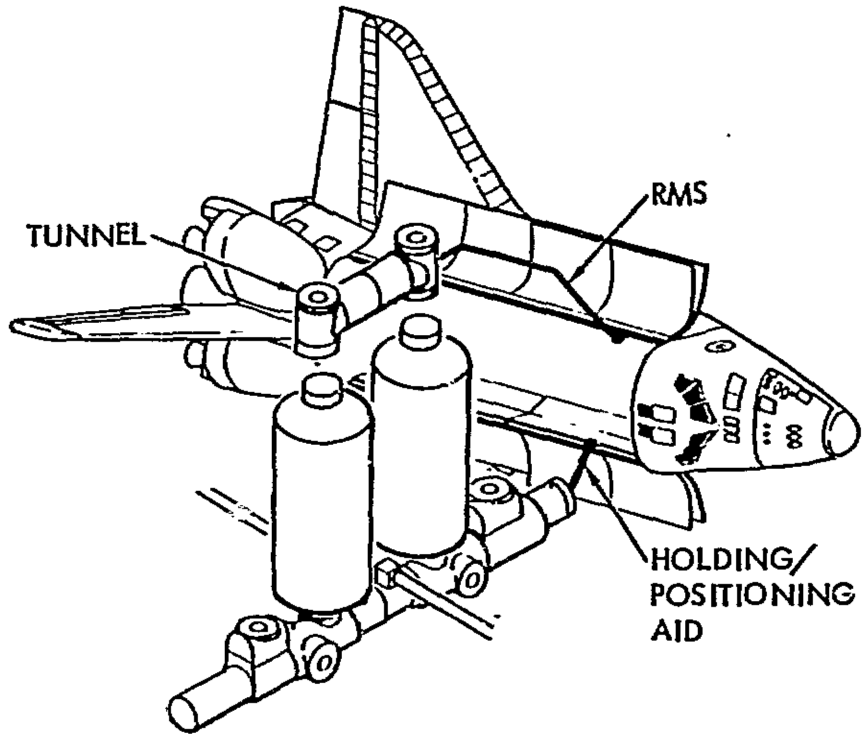
RMS TUNNEL INSTALLATION

ORBITER RMS WITH DOCKING MODULE



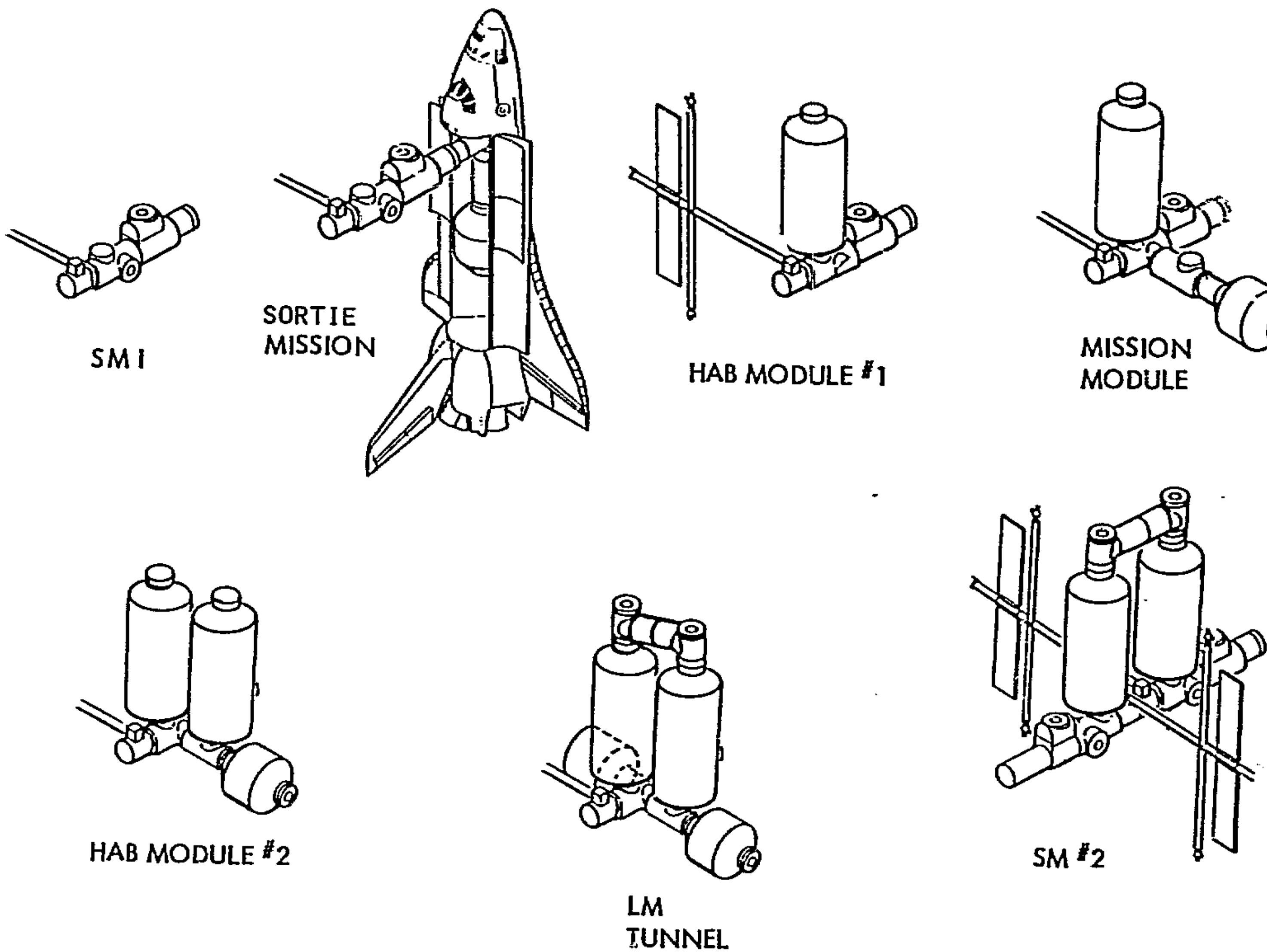
• INSUFFICIENT REACH CAPABILITY OF RMS

ORBITER RMS WITH HOLDING AND POSITIONING AID



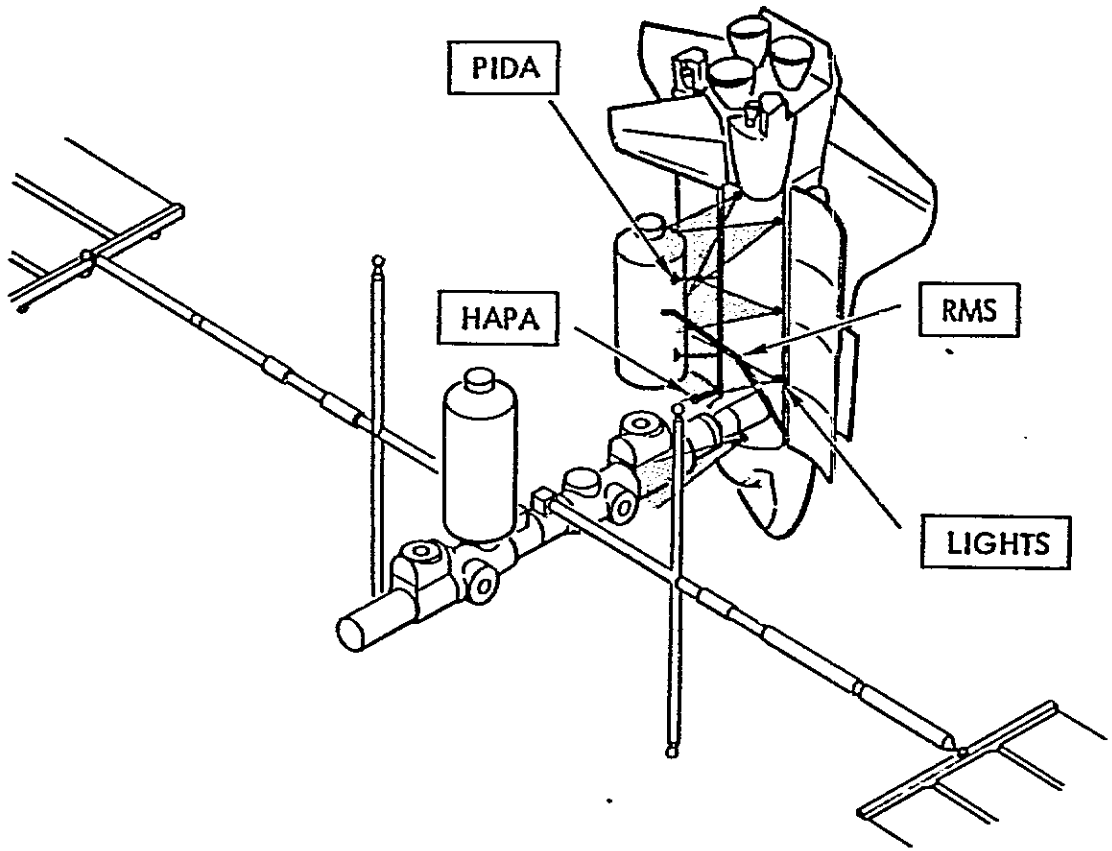
• WITHIN REACH CAPABILITY OF RMS.

EXAMPLE OF AN EVOLUTIONARY BUILD-UP



ASSEMBLY PROVISIONS ABOARD ORBITER.

ORBITER PROVISIONS IN DEVELOPMENT OR PLANNED



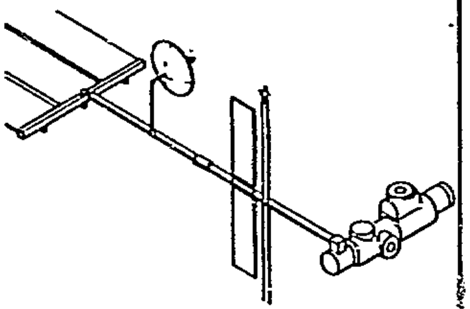
ASSEMBLY IMPACTS ON SOC DESIGN

There are several SOC implications which must be considered in order to accommodate all possible buildup modes, basic or evolutionary. Considering the assymetric configuration of a fully deployed Service Module, an interim attitude stabilization for safe revisit is required. Similarly, an independent environmental control life support system is required on the habitation module in order to afford maximum flexibility in the buildup sequence. In the event of a buildup sequence that orients the two habitation modules different than the normal operational orientation, then a clocking capability on the tunnel interface could also be required. These features represent few added provisions that must be incorporated into the SOC so it can accommodate all possible buildup modes.

ASSEMBLY IMPACTS ON SOC DESIGN

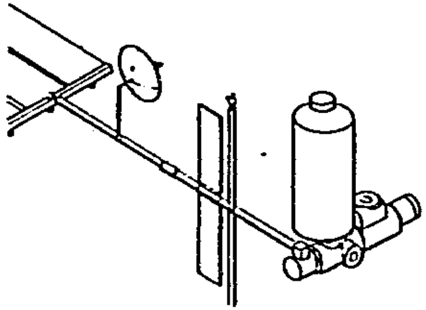
FEW Δ PROVISIONS REQUIRED OF SOC TO ACCOMMODATE ALL POSSIBLE BUILD-UP MODES

SM



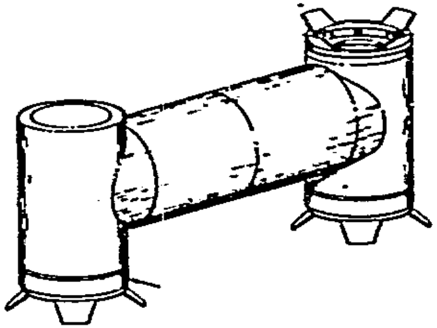
- INTERIM ATTITUDE STABILIZATION FOR SAFE REVISIT

HAB. MODULE



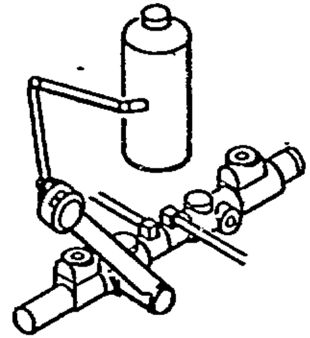
- SHOULD HAVE INDEPENDENT ECLSS FOR MAX FLEXIBILITY

TUNNEL



- PROVIDE FOR POTENTIAL CLOCKING

RCM



- NO IMPACT

C-2

SUMMARY

- SOC CAN BE DESIGNED TO ACCOMMODATE NOMINAL AND EVOLUTIONARY MODES OF BUILT-UP AND VARIATIONS OF THOSE MODES
- VERY LITTLE Δ PROVISIONS ARE REQUIRED FROM THE ORBITER AND FROM SOC TO ACCOMPLISH ALL POSSIBLE BUILT-UP MODES
- TIMING OF THE RCM INSTALLATION CAN BE SIGNIFICANT TO SOC BUILD-UP
- A HIGH-CONFIDENCE TECHNIQUE FOR THE ASSEMBLY OF SOC MODULES IS PROPOSED

BRIEFING OUTLINE

EXECUTIVE SUMMARY

ORBIT ALTITUDE STRATEGY

BERTHING & DOCKING

SOC BUILDUP & ASSEMBLY CONCEPTS

CONCLUSIONS & PLANS

CONCLUSIONS

- ORBITAL ALTITUDE
  - SOC SHOULD FLY A VARIABLE ALTITUDE STRATEGY
  - STANDARD ORBITER CAN DO THE JOB
- BERTHING AND/OR DOCKING
  - A STANDARDIZED DOCKING MECHANISM AND DOCKING MODULE CONCEPT HAS BEEN DETERMINED AND PRELIMINARY REQUIREMENTS DEFINED
  - STATUS OF THE ORBITER MCR AND OF THE 25 KW POWER SYSTEM PROGRAMS DEMAND EARLY DEFINITION OF THE REQUIREMENTS AND CONCEPT
  - ORBITER HAS ADEQUATE CONTROLLABILITY TO DOCK WITH SOC -- BUT SOLUTIONS MUST BE FOUND FOR RCS FAILURE MODE
- SOC ASSEMBLY
  - SOC SHOULD BE AND CAN BE DESIGNED TO ACCOMMODATE NOMINAL AND EVOLUTIONARY MODES OF BUILD-UP
  - WITH ASSEMBLY AIDS CURRENTLY IN DEVELOPMENT OR PLANNED, ORBITER CAN ACCOMMODATE ANY MODE OF SOC BUILD-UP

PLANNED ACTIVITY